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Feasibility and Demonstration of Network Simulation Techniques for Estimation of Emissions in a Large Urban Area

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

Feasibility and Demonstration of Network Simulation Techniques for Estimation of Emissions in a Large Urban Area

Final Report

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ABSTRACT

Recent requirements for reducing air pollutant emissions set forth by the California and Federal Clean Air Acts require development of improved techniques for estimating emissions from motor vehicles, and assessing the effectiveness of emission control measures. A full understanding of the mobile source emissions burden requires a better representation of the driving modes that produce extraordinary levels of emissions, particularly accelerations, and there is great interest in predicting vehicle activity by mode of operation. The objective of the study described in this report was to develop an integrated modeling framework to produce detailed emission inventories for large urban areas.

Alternative approaches for an integrated model were developed, including ways for directly linking the traditional four-step planning models with microscopic network simulation models, and indirect sampling techniques consisting of relationships between vehicle activity and link characteristics. The alternative approaches were evaluated considering accuracy of predictions, input data and computational requirements, and the state-of-practice in regional modeling. The sampling approach had the highest cost-effectiveness for regional studies, and was selected for implementation.

Relationships were developed between the time spent in each driving mode and basic link characteristics based on simulations of selected real-world surface street networks and freeway sections using the TRAF-NETSIM and INTRAS models, supplemented by field data. These relationships were then incorporated in a specially written computer program as a post-processor to the widely used MINUTP planning model. The integrated model was applied to the entire 1120 zone MTC San Francisco Bay Area network to obtain the time-spent per driving mode. The analysis of the results demonstrated the applicability of the model to predict vehicle activity in regional studies. The report also provides recommendations for improving the modeling techniques for air quality analysis.

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Alexander Skabardonis served as the Principal Investigator and Senior Researcher for the study. He was assisted by Greig Harvey of DHS. Dr. Richard Dowling, principal of Dowling Associates assisted in the model development, and the simulation experiments. Ms. Ann Stevens of Ann Stevens Associates assisted in the demonstration of the model.

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CHAPTER 1

INTRODUCTION

1.1 Statement of the Problem

Recent requirements for reducing air pollutant emissions set forth by the California and Federal Clean Air Acts require development of improved techniques for estimating emissions from motor vehicles, and assessing the effectiveness of emission control measures.

Traditionally, the amount of air pollutant emissions from motor vehicles is estimated from trip and vehicle-miles of travel (VMT) based emission factors and appropriate measures of vehicle activity (including average vehicle speed). The emission factors used by the California Air Resources Board (ARB), Environmental Protection Agency (EPA) and other agencies are based on the Federal Test Procedure (FTP) driving cycle. Correction factors for average speeds are available, and data currently are not provided on emissions in each driving mode (e.g., cruise, idle, acceleration, and deceleration.) This has not been a significant problem in the past, because the commonly used models for planning and operations studies do not produce routine information about driving mode. For example, the typical four-step travel demand model (trip generation, distribution, modal split and traffic assignment) for a region provides only estimates of the average speed on each link.

Recent work by ARB and others has made it clear that a full understanding of the mobile source emissions burden will require a better representation of the driving modes that produce extraordinary levels of emissions, particularly accelerations. In part because of the success of current controls in reducing steady state emissions, the acceleration phase of the driving cycle has assumed much greater importance than it had when the FTP was first developed. It is feared that analyses based on average speed may lead to large differences from the actual values, especially in places in the system where acceleration profiles deviate significantly from FTP assumptions.

In light of these developments, there is some interest in investigating ways for simulating the driving patterns of individual vehicles in a region and of predicting vehicle activity by mode of operation. ARB (and EPA at the national level) could provide modal emission factors. The capability of modeling vehicle operational modes is currently available on a limited scale in existing network simulation models; however, the input data and computational requirements make those models suitable mainly for small area studies.

Tremendous improvements in computer speed, memory size, and software technology offer the potential to use microscopic network simulation models feasible for much larger networks, thus allowing the analysis of emission control measures in regional studies. The interface of such models with the standard four-step demand models would provide an integrated modeling framework for predicting the impacts of a wide range of emission control measures in a region. Alternatively, a sampling strategy in which only the most problematic locations were treated microscopically might offer a less demanding way of improving the accuracy of emissions estimates without the level of system and software development required for a regionwide microscopic model.

1.2 Overview of the Project

The purpose of this study is to evaluate the feasibility of integrating the traditional four-step demand modeling process with some degree of detailed network simulation models to produce detailed emission inventories, and to demonstrate its application in a metropolitan area. The study had the following objectives:

- **Evaluate the feasibility of using network simulation techniques in conjunction with the four step travel-demand modeling process:** investigate how microscopic simulation models will be integrated with the regional planning models to produce detailed vehicles' activity data by mode of operation, and design a demonstration project to test the integrated model.

- **Demonstrate the use of the integrated model in a large urban area:** develop the integrated model and apply it to a portion of the Metropolitan Transportation Commission's (MTC) San Francisco Bay Area network.

The study consisted of two major phases. In Phase I, alternative approaches for an integrated modeling system were formulated and evaluated. A demonstration project was also designed to develop and apply the most promising model. The work performed and the findings were written in a technical report (31). Following the approval of the technical report, the development and demonstration of the model, and the analysis of the results were undertaken in Phase II of the project.

1.3 Organization of the Report

This is the final report for the project. It describes the methodology, model development, and presents the findings from the demonstration. Chapter 2 briefly reviews the existing procedures for estimating emissions, and the state-of-the-art planning and network simulation models. The alternative approaches for developing an integrated model, the evaluation of the alternatives and the proposed modeling system are described in Chapter 3. Chapter 4 describes the development of the model, and Chapter 5 presents the findings from the application of the model to the MTC Bay Area network. The major findings of the study are summarized in Chapter 6 along with recommendations on emission estimation procedures and suggestions for future research.

CHAPTER 2

BACKGROUND

This Chapter provides an overview of the vehicle emission estimation procedures, briefly describes the state-of-the-art techniques in travel demand forecasting and network simulation models, and describes the evaluation process for selecting the component models for the integrated modeling system.

2.1 Estimation of Emissions

The three major pollutants released by motor vehicles are: hydrocarbons (HC), carbon monoxide (CO) and oxides of nitrogen (NO_x). The majority of emissions come from gasoline-powered motor vehicles. The majority of hydrocarbon emissions from automobiles come from the unburned fuel-air mixture released in the exhaust gases. Carbon monoxide emissions also result from incomplete combustion due to inadequate oxygen in the fuel-air mixture. Nitrogen oxides, in contrast, are a product of relatively efficient burning; they result from the transformation of the free nitrogen present in the air. The amount of vehicle emissions depends on several factors including the amount of travel, driving mode (cruise, idle, acceleration, deceleration), vehicle characteristics (type of vehicle, age, size, engine type, transmission system, antipollution devices, type of gasoline used), vehicle operating conditions (hot .vs. cold starts, engine temperature, in vehicle load, speed of vehicle), environmental conditions (altitude, ambient temperature), and roadway conditions (horizontal and vertical alignments.)

Traditionally, the amount of air pollutant emissions from motor vehicles is estimated from trip and vehicle-miles of travel (VMT) based emission factors and appropriate measures of vehicle activity (including average vehicle speed). Several assumptions are used for the other factors. The VMT and average speed are obtained from the output of the four-step travel demand models. The average speed, however, is a highly approximate representation of the actual driving patterns especially for congested links, and it was found that this approach could underestimate the emissions by up to 60 percent depending on the percent of link that is congested (6). In addition, the speeds predicted by the existing demand models are not accurate, because such models do not explicitly consider the effects of queuing in the analysis. Recently, a methodology was proposed to improve the speed estimates from planning models (6). This methodology was applied in a regional model and comparisons with predicted speeds from simulation models showed that the proposed approach did improve the accuracy of the estimated speeds.

A more accurate estimation of emissions requires a better representation of the vehicle activity. Figure 2.1 shows the trajectories of vehicles as they travel along an arterial with signalized intersections, and illustrates the difference in vehicle activity for the same average travel speed. Both vehicles B and C travel at the same average speed and suffer the same amount of total delay; however, vehicle B has to decelerate, stop and accelerate at each traffic signal, thus emitting a higher amount of pollutants than the vehicle C which stops only at the first intersection.

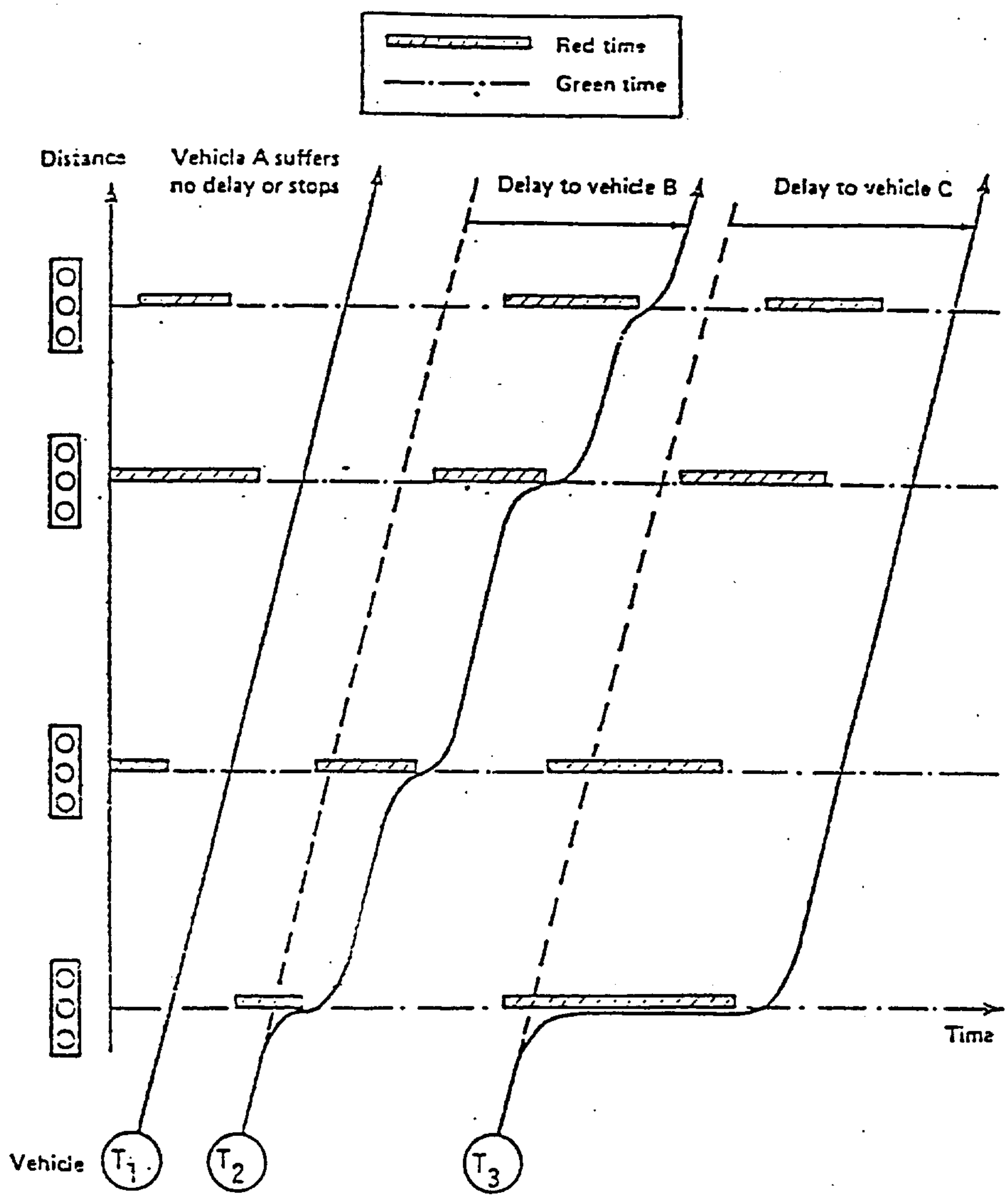


FIGURE 2.1 IMPORTANCE OF VEHICLE ACTIVITY IN EMISSIONS ESTIMATION

The estimation of emissions based on the time spent and the emission rate per unit time for each driving mode has been implemented in a number of network simulation models. The amount of vehicle emissions for a network link is calculated as follows:

$$E_i = \sum_{n=1}^{N} a_n \sum_{j=1}^{K} e_{ijn} T_j \tag{2-1}$$

where:
E_i: emissions for pollutant i (gr/h)
N: number of vehicle types in the traffic stream
a_n: proportion of vehicle type n in the traffic stream (%)
e_{ijn}:emission factor for pollutant i and driving mode j for vehicle type n
T_j: time-spent in driving mode j (veh-h)
K: number of driving modes

An example of this approach are the emissions estimation routines developed and incorporated into the SOAP, PASSER-II and TRANSYT-7F models for isolated intersections, arterials and networks (35). These routines calculate the time spent in acceleration/deceleration and idling from the original models' predicted total travel time delay and stops, and external inputs on acceleration and deceleration rates at traffic signals. The modal emission factors used were abstracted from the EPA Modal Analysis Model for California conditions and the ARB's EMFAC model. The emission factors for cruise, acceleration and deceleration were expressed as a function of the cruise speed. Emission factors were developed separately for autos, light duty trucks, medium duty trucks, heavy duty trucks and busses.

The major limitation of macroscopic models, however, is that they estimate the time spent in each driving mode based on the average flow rates or platoons of vehicles and certain simplified assumptions (i.e., constant rates of acceleration/deceleration) instead of the detailed simulation of each vehicle's travel paths. Microscopic simulation models in contrast can estimate the time-spent by driving mode more accurately because they consider the characteristics of individual vehicles and their interactions, and they produce detailed trajectories of each vehicle as it travels in the network (e.g. the TRAF-NETSIM model for urban networks, and the INTRAS model for freeways). The emissions estimation is based on modal emission factors as a function of the speed and acceleration/deceleration and vehicle type [22]. Users can override the default emission rates in those models without software modification.

Microscopic simulation models so far have been applied to small area studies because they require additional data and computer resources than the other techniques. They also require as inputs the total volume and turning movements for each network link. Such data should be estimated from a planning model especially for assessing the impacts of traffic growth or demand management in large urban areas. Therefore, both types of models have to used for accurately estimating emissions in a region; the four-step demand model would provide the link volume as inputs to the network simulation model which in turn would predict the time spent by driving mode.

2.2 Travel Demand Models

Traditional travel demand models consist of four sequential steps: trip generation, trip distribution, modal split and traffic assignment. The prototypical model of this type was implemented on a mainframe computer in the Urban Transportation Planning Package (UTPS) modeling system. More recently, several workstation and microcomputer implementations have been developed, including MINUTP, TRANPLAN, EMME2, SYSTEM II, TMODEL and QRS. All of these models follow the same four-step modeling framework. Differences between the software packages are in the areas of i) user interface (options and quality of graphic displays, editing functions, data entry and manipulation), ii) output options (e.g., estimation of turning movements, delays and level of service at intersections, network plots), iii) network size that can be analyzed (maximum number of traffic zones, links and nodes), iv) transport modes that can be handled (number of modes, number of transit lines), and v) library of algorithms available for each modeling step (e.g., gravity and growth factor models for trip distribution).

Several planning organizations have implemented variations of the UTPS type model. The original MTC four-step travel demand model employs a variant of the four-step process (MTCFCAST 80/81) and is directly compatible with the UTPS software package (25). Figure 2.2 shows the structure of the MTC model. The modal choice, trip distribution, trip generation, and auto ownership models are placed in a innovative hierarchical framework that emphasizes the interaction and feedback among travel choices. MTC's traffic assignment technique is a capacity restraint equilibrium assignment. The MTC model includes an "equilibration" process. Congested travel times from the highway and transit assignments are cycled back through the model hierarchy as far as necessary to achieve consistency. This iterative process can continue until an equilibrium is reached and the travel times and speeds for highway and transit networks are reasonably consistent with the output speeds and times.

Recently the MTC Bay Area network was updated and coded for the MINUTP software (4). MINUTP consists of a series of linked independent modules. Trip generation is performed through regression equations for productions and attractions as a function of zonal socioeconomic characteristics. The gravity model is the default technique used for trip distribution, and the logit model for modal split. Several options are provided for the traffic assignment including all-or-nothing, capacity restraint, equilibrium and stochastic multipath assignment. Input data required for the network building and the assignment module consist of the basic link characteristics of the network (distance, number of lanes, free flow speed and capacity). The output from the model includes the traffic volume (turning movements), VMT, total travel time, average speed and volume/capacity ratio for each network link. The program includes an interactive data input and editing routine (NETVUE) and the NETMRG utility routine for manipulating input and outputs.

MINUTP uses the following equation (referred as the BPR formula) to adjust the link speeds (travel times) in the traffic assignment module:

$$V_c = V_o/(1 + \alpha(v/c)^b) \tag{2-2}$$

where:

V_c: *congested speed (mph)*
V_o: *free-flow speed (mph)*
(v/c):volume to capacity ratio
a,b:coefficients (defaults a=0.15, b=4)

The model allows to specify up to 63 separate speed/capacity classes and different coefficients in the equation (2.2) to better simulate the operational characteristics of different link types in the network (e.g., freeways, arterials.) However, as it was discussed in the previous section, MINUTP and the rest of the planning models cannot explicitly consider queuing on the network links, or to perform multiple period assignment. This would result in unrealistic estimates of speeds and travel times especially for emissions estimation.

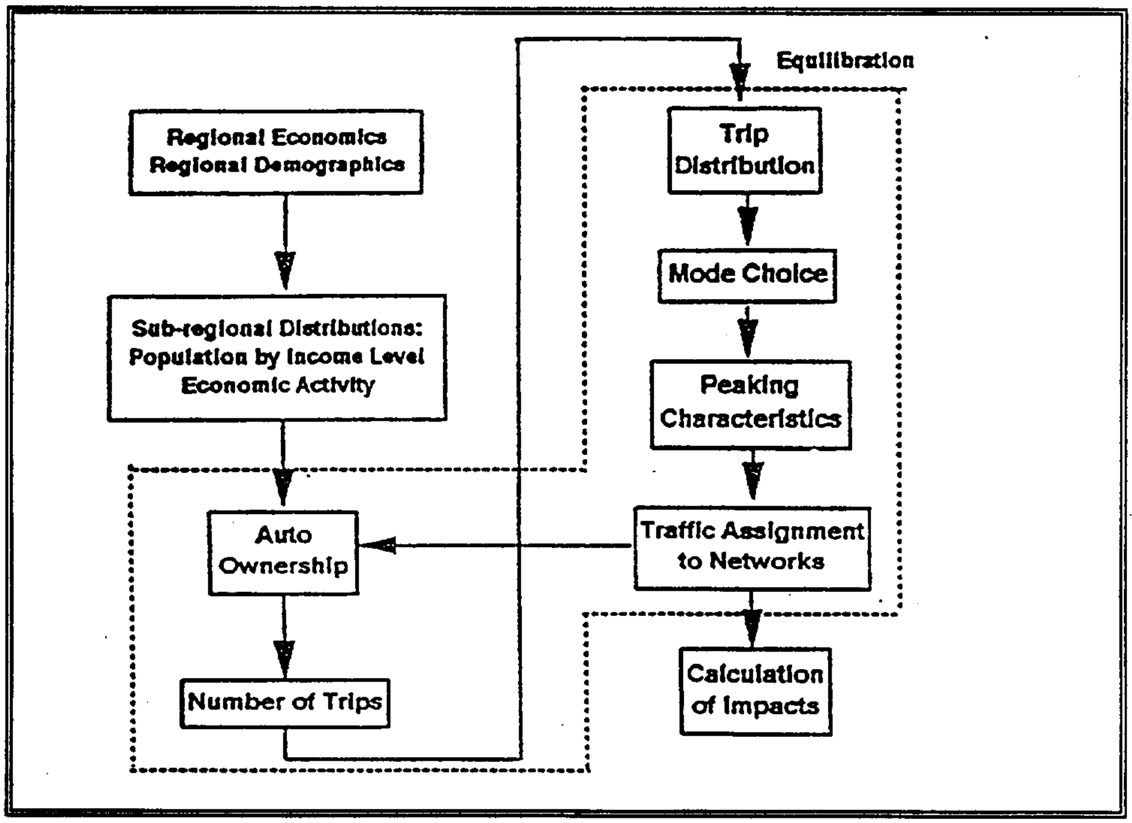


FIGURE 2.2 STRUCTURE OF THE ORIGINAL MTC MODEL

2.3 Network Simulation Models

Several models have been developed over the last twenty years to simulate traffic flow on highway facilities (21,36). These models generally fall into two major categories. Macroscopic models consider the average traffic stream characteristics (flow, speed, density) or platoons of vehicles, and incorporate analytical procedures to simulate traffic operations. Microscopic models consider the characteristics of individual vehicles, and their interactions in the traffic stream. Table 2.1 below shows the state-of-the-art models and their characteristics that are used for modeling various types of highway facilities.

TABLE 2.1 EXISTING NETWORK SIMULATION MODELS

MODEL TYPE/ CHARACTERISTICS	FREEWAYS	SURFACE STREETS	CORRIDORS
Macroscopic Speed/flow density relationships Conventional designs Optimization O-D estimation/Assignment	FREQ10 FREFLO (FRECON) KRONOS	PASSER II-90 TRANSYT-7F CONTRAM* SATURN*	CORFLO* FREQ10
Microscopic Individual vehicles Deterministic/stochastic Various design/control options No optimization/Assignment	INTRAS (FRESIM)	TRAFFICQ NETSIM	ATMS*+ INTEGRATION TRAF+

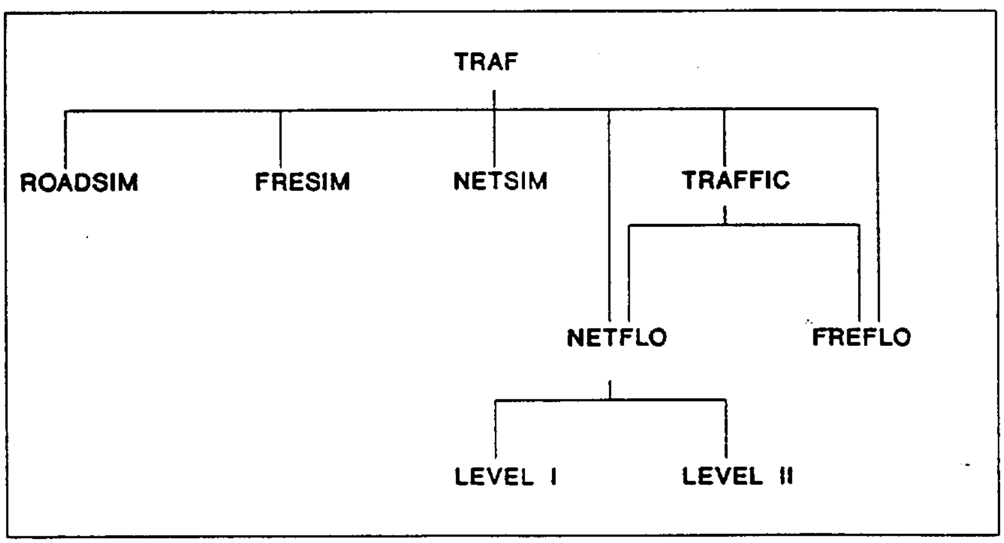
NOTES:
** Includes traffic assignment algorithm*
+ Under development

Macroscopic freeway models: The **FREQ10** model (15) simulates traffic flow based on speed-flow relationships and shock-wave analysis. It can model capacity reductions and High Occupancy Vehicle (HOV) facilities, and determines the optimal rates for ramp metering schemes including priority lane and priority entry control. Input data consist of the design characteristics, and the origin-destination matrix at 15 min time slices. The output includes several performance measures and environmental impacts. The **FREFLO** model (27) is based on the conservation equation and a dynamic speed-density equation. It simulates different vehicle classes (busses, carpools), HOV facilities, and traffic incidents but it cannot model ramp operations. **FRECON** (1) is a modification of the FREFLO model to improve the accuracy, simulate real-time control algorithms and estimate fuel and emissions. **KRONOS** (26) simulates traffic flow including lane changing, merging and weaving maneuvers based on equilibrium speed-density relationships.

Macroscopic surface streets models: The **PASSER-90** model (2) is primarily used on signalized arterials. It optimizes the signal settings (cycle length, green times and offsets) to maximize the green bandwidth for the arterial, and estimates delay, stops and queue lengths. **TRANSYT-7F** (38) is the most widely used model to simulate the performance of arterials and networks with traffic signals and optimize the signal settings for minimum delay and stops. TRANSYT simulates the movement of platoons of vehicles and predicts travel times, delay, stops, queue lengths and fuel consumption. **CONTRAM** (17), developed at the Transport Research Laboratory (TRL) in England, is mainly used for evaluating traffic management schemes in urban networks. The model includes a dynamic traffic assignment which explicitly considers queuing and can also perform iterative multiple time-period assignment. Link travel times are updated based on macroscopic simulation of traffic flow. **SATURN** (44) is a similar model to CONTRAM also developed in England. It consists of a macroscopic traffic flow model and an equilibrium assignment algorithm.

Macroscopic corridor models: The **CORFLO** modeling system (16) developed for the Federal Highway Administration (FHWA) consists of an ensemble of models to simulate traffic diversion. The freeway portion of a network is simulated with the **FREFLO** model. Traffic flow on the surface streets can be simulated microscopically with the NETFLO I model and macroscopically with the platoon based NETFLO II model. This allows the simulation of portions of the same network at a different level of detail. Traffic is assigned to the different subnetworks using the **TRAFFIC** assignment model. Note that CORFLO is part of the TRAF modeling system which also includes the TRAF-NETSIM, FRESIM and ROADSIM microscopic simulation models (Figure 2.3.) The FREQ10 model also can simulate traffic corridors consisting of a freeway and a single parallel arterial. Travel times on the arterial are estimated based on the Davidson's formula (5).

FIGURE 2.3 THE TRAF MODELING SYSTEM



Microscopic freeway models: The **INTRAS** (Integrated TRAffic Simulation) microscopic simulation model (39,40) was originally developed for the FHWA in late 70's. It simulates the movement of each individual vehicle on the freeway and the ramps based on car-following, lane changing and queue discharge algorithms. INTRAS can simulate various design configurations and control and management strategies (e.g, ramp metering, HOV lanes, incident detection). The model is written in FORTRAN and is operational on mainframes and IBM compatible 386/486 microcomputers. Recently, a number of major modifications and enhancements to the model resulted in a new model **FRESIM** to succeed INTRAS (12). This model includes better representation of driver behavior, improved logic for merging and lane changing, modeling of real-time ramp metering schemes and interaction with the traffic in the adjoining local networks. Input data consist of design characteristics (length, number of lanes, location and length of the acceleration and deceleration lanes, grade and curvature), traffic characteristics (free-flow speeds, vehicle composition, traffic volumes, and origin-destination data), location and type of control devices (warning signs, detectors, ramp metering schemes.) The output includes estimates of travel time, delay, fuel consumption and emissions.

Microscopic models--surface streets: The **TRAFFICQ** model (18) was developed in England in the early 80's to simulate in detail alternative control and traffic management schemes. This program has not been used in the US and its application would require calibration of the model parameters for US conditions. **TRAF-NETSIM** (9,28) is the latest version of the NETSIM (Network Traffic SIMulation) model (8) originally developed for the FHWA in the early 70's. It provides a detailed simulation of alternative designs and traffic control strategies ranging from stop signs to traffic responsive control, for isolated intersections, arterials and networks considering the movement and interactions of individual vehicles. The model can also handle transit movements, parking activity, and street blockages. TRAF-NETSIM is written in FORTRAN 77 and is operational on both mainframes and PC386/486 based microcomputers. A post-processor with graphical displays and animation of vehicle movements facilitates the verification of the input coding and interpretation of the results. Input to the NETSIM model consists of design characteristics for each link (length, number of lanes, type and length of turning lanes, grade, lane usage), free flow speed, saturation flow and lost time at traffic signals, traffic volumes per time period, traffic control (traffic signals/stop signs, signal settings, detector type and location). The output includes travel time, delay, stops, fuel consumption, and emissions.

Microscopic corridor models: Microscopic simulation of traffic corridors has so far been limited because of the intensive data and computational requirements for simulating traffic flow in large networks. Recently, the need for assessing the potential benefits of strategies within the area of intelligent-vehicle-highway systems (IVHS) has prompted the development of microscopic models for traffic corridors with dynamic traffic assignment capabilities. These models assign vehicles on highway facilities based on real-time information on traffic conditions in the network and simulate the performance of in-vehicle information and route guidance systems. Examples include the **INTEGRATION** model (42,43) which simulates the traffic movements of individual vehicles including those with route guidance systems. **ATMS** (14) currently under development is a dynamic traffic assignment model which employs parallel processing to assign large number of vehicles based on real-time link travel times. Also, the FRESIM (INTRAS) and TRAF-NETSIM models employ compatible data formats and could be used to simulate traffic corridors of freeways and adjoining surface streets.

2.4 Evaluation and Selection of Models

The state-of-the art models described above were evaluated in detail considering their computational aspects, algorithms, data inputs, and output options to select the models best suited for developing the integrated modeling system for emissions estimation. The MINUTP model was selected as the four-step planning model because it has been widely used in practice, and is also employed in the MTC Bay Area network which is the test site for the demonstration project. The following criteria listed in order of importance were used to select the network simulation models:

- Provide vehicle activity data: As explicitly stated in the project's scope of work, the integrated model should estimate the time-spent in the following driving modes (Table 2.2): seven acceleration modes, from 1 to 7 mph/sec, seven deceleration modes, from -1 to -7 mph/sec, 13 cruise modes classified by the midrange speed from 5 through 65 mph., and the idle mode.

TABLE 2.2 PROPOSED OUTPUT FORMAT FROM THE INTEGRATED MODEL
Time Spent In Each Driving Mode (Veh-h)

	DECELERATION/ACCELERATION (mph/sec)														
SPEED(mph)	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7
0								IDLE							
5															
10															
15															
20															
25															
30								CRUISE							
35															
40															
45															
50															
55															
60															
65															

- Handle traffic, design and control characteristics commonly occurring in the field: Ability to simulate several design and control strategies on freeways and surface streets and the interactions between the two facility types.

- Available, well documented and applied in practice or research projects: Evidence from other studies that produce reliable results. Sufficient documentation to permit both straightforward model applications and handling of special conditions.

- Availability of the source code: to permit modifications and enhancements as needed for developing the integrated model.

- Traffic assignment capability: to refine the link volumes and speeds produced by the regional model taking into consideration queuing and other factors.

- Optimization: to directly generate alternative measures for emissions reduction, including spatial and temporal demand management, traffic management, and design/circulation modifications.

None of the existing simulation models satisfies all of the above criteria. TRAF-NETSIM and INTRAS (FRESIM) are the only models that produce vehicle trajectories to obtain the time spent in each driving mode. Both models have been used extensively as research and practical evaluation tools, their documentation appears satisfactory and the source code is available (except for the FRESIM model), but they cannot perform traffic assignment or optimization. INTEGRATION is the only microscopic model with traffic assignment and optimization capabilities, but it does not provide vehicle activity data. Its potential application would be to refine the MINUTP assigned link volumes and speeds for input to INTRAS/NETSIM. This, however, would require significant effort in developing models interface software because INTEGRATION is proprietary and the source code is not available.

Traffic assignment and optimization could be accomplished through macroscopic models. For example, CORFLO could be used to determine the turning fractions for input to the microscopic models. However, the TRAFFIC submodel of CORFLO cannot perform dynamic traffic assignment, and the interfaces between the microscopic models and CORFLO within the TRAF modeling system are not as yet completed. CONTRAM and SATURN, however, are capable of realistic traffic assignment and optimization. CONTRAM was recently used to evaluate the effectiveness of traveller information systems in the Los Angeles "smart corridor" (11). The findings indicated that the model cannot simulate freeways accurately since it was originally designed for surface street networks. The input data requirements were similar to the rest of the traffic operations models, and considerable effort was spent in data coding and calibration, often with the direct assistance of the model developers. The use of CONTRAM would require additional model interfaces to link it with the other models. Note that CONTRAM (and SATURN) are proprietary and the availability of their source codes is limited.

The evaluation of the models based on the above criteria showed that the TRAF-NETSIM and INTRAS models are best suited to the project objectives and were selected to be used in conjunction with MINUTP for developing an integrated modeling system.

CHAPTER 3

FEASIBILITY OF AN INTEGRATED MODEL

This Chapter describes the approaches developed for integrating the network simulation models into the four-step demand model, and presents their evaluation and selection of the most promising approach. Three alternatives were formulated for developing an integrated model and described below. The first two aim in developing a "new" model consisting of both the planning and simulation models. The third approach consists of the planning model and a post-processor with relationships between link characteristics and vehicle activity data. Such relationships would be derived using the simulation models on sample networks.

3.1 UTPS Post-Processor I

This approach consists of sequentially linking the four-step travel demand model and the network simulation model (Figure 3.1). The link traffic volumes output from the assignment step of the regional model would be input to the simulation model(s). The simulation model(s) would then run to produce estimates of the traffic performance and the time spent by vehicles in each driving mode.

3.1.1 Data Requirements and Models Interface

Table 3.1 shows the input data required for the application of the selected models. Several data items are common to both types of models. Also, the link volumes and turning movement output from the regional model are inputs to the simulation models. The simulation models, however, require additional information including detailed geometrics per each intersection approach, type and characteristics of the control devices (stop-signs, traffic signals, ramp meters,) as well as driver-vehicle characteristics.

The linkage of the models requires conversion of the input/output data from MINUTP in a format suitable for running the simulation model. Also, the regional implementations of MINUTP such as the MTC San Francisco Bay Area model provide for a simplified representation of the highway network. The network simulation models, however, require detailed network coding at the intersection/approach level. Therefore, the network should be refined through zone splitting and coding of additional links and nodes. Note, that the refined network should still be compatible with the original regional model.

The model linking process would consist of collecting additional data, and developing routines for network refinement and data conversion. This includes adding links and nodes to represent the network at the required level of detail for the simulation models. The MINUTP procedures of subarea, select link analysis and the MATCON (matrix conversion) routine will be utilized for the network refinement and defining the trip table for the subarea of interest. The NETMRG routine will be used for developing the basic structure of a NETSIM/INTRAS model input deck including program controls, and to convert the link/node data in MINUTP into the simulation model data file.

FIGURE 3.1 UTPS POST-PROCESSOR I APPROACH

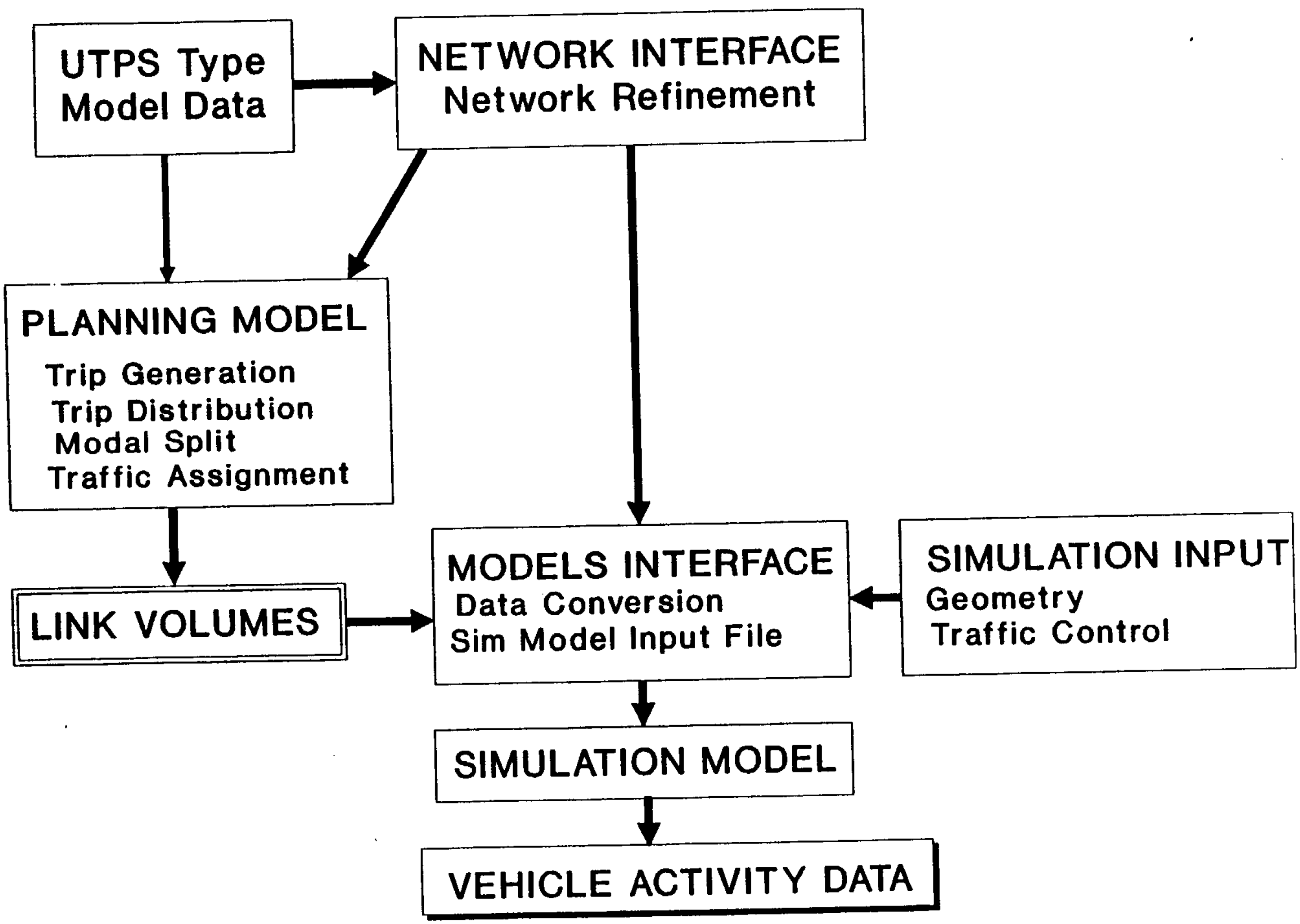


TABLE 3.1 INPUT DATA REQUIRED FOR THE MODELS' APPLICATION

		MODEL	
DATA TYPE	MINUTP	NETSIM	INTRAS
Network Data			
Node Coordinates	X	X (O)	X (O)
Link Distance	X	X	X
Number of Lanes	X	X	X
Lane Usage		X	X
#/type Pockets		X	
#/type Auxiliary Lanes			X
Link Type		X (O)	X (O)
Saturation flow		X	X
Lost Time		X	X
Capacity	X		
Speed-Flow Curve	X		
Free Flow Speed	X	X	X
Pedestrian Activity		X	
RTOR		X	
Traffic Demand Data			
Land Use/Socioeconomic characteristics	X		
Network Entry Volumes		X	X
Traffic Composition		X	X
Turning Movement Counts		X	X
O-D Table			X
Traffic Control Data			
Type of Control Device		X	X
Timing Plan in Operation		X	
Phasing		X	
Tming Plan in Operation		X	
Detector Type/Location		X	X
Actuated Controller Parameters		X	
Ramp Metering Plan			X

Sample command files using NETMRG were written and tested with limited data and showed the feasibility of this approach. The additional data for the simulation models including lane channelization and lane usage will be edited in the file prepared from the NETMRG utility. Traffic control data will be prepared and coded externally and merged later into the basic input data deck.

It should be also noted that the NETSIM and INTRAS models are not currently connected so simulations have to be performed separately for the freeway and the surface street networks. Additional software development would be required to complete the linkage of these models. This effort is currently underway for linking the FRESIM and TRAF-NETSIM within the TRAF modeling system.

3.1.2 Computational Aspects

The memory requirements and the running time of the microscopic models depend on several factors including the network size (number of links and nodes), number of vehicles to be processed (related to the traffic volume and density, and the link length), duration of the simulation run, traffic control systems to be simulated (e.g., fixed-time signals .vs a surveillance system with detectors and traffic responsive control,) and output options (estimation of fuel consumption and emissions.)

The latest version 4.0 of the TRAF-NETSIM model can handle 250 nodes (with a maximum of 18 actuated signals), 500 links, and 3,000 vehicles. This translates into simulating a four lane arterial and side streets with 50 signalized intersections (e.g., a 12 mile long section of the San Pablo Ave arterial in the San Francisco Bay Area.) The running time for this application is approximately 10 min of CPU time on a IBM3091 mainframe for a 30 minute simulation with 5 min network loading ("warm-up") time. Large networks can be simulated using supercomputers. The NETSIM simulation of the Austin network with 600 nodes and 1,600 links on a Cray supercomputer produced promising results (19). Approximately 7,000 vehicles were processed at a CPU time of about 20 min. These findings, however, should be interpreted with caution because stop sign control was simulated for only 10 minutes of simulation time and vehicle trajectories were not written. The execution times would be considerably higher for simulating other types of control, longer simulation periods and processing of vehicle trajectories. Regarding the INTRAS model, a recent application on a 7 mile section of the SR55 freeway in Orange County, California with three parallel arterials consumed 3 hours of CPU time on an IBM mainframe to process 3,000 vehicles. The simulation of the Bay Area freeway network consisting of about 500 miles with 550 segments with INTRAS would require approximately 2,000 directional links, 1,000 nodes (including ramps, weaving sections, freeway connectors), and processing of about 20,000 vehicles.

The above discussion points out that the application of microscopic models in large networks would require both software modifications and use of fast computers. The program arrays for links, nodes and the maximum number of vehicles should be increased for modeling a large urban area. This involves changes in the COMMON blocks in the main routines of the INTRAS and NETSIM programs. Also, the programs' source code should be modified for higher computational efficiency. This would performed in the book-keeping routines (CLNUP) through code vectorization (20).

3.1.3 Simulation Models Output

Currently the output from the selected simulation models provides moving and stopped (idle) travel time estimates; it does not provide directly the time spent in cruise, acceleration, deceleration, and idle driving modes. This information can be extracted from the vehicle trajectory file written by the models. A set of routines would have to be written to extract the data from the trajectory files and produce the estimates of vehicle activity in a tabular format as shown in Table 2.2. However, vehicle trajectory files require large storage space and increase the running times of models. An alternative approach best suited for simulating large networks is to modify the INTRAS and NETSIM output modules to store and print-out the vehicle activity data at the end of the simulation run.

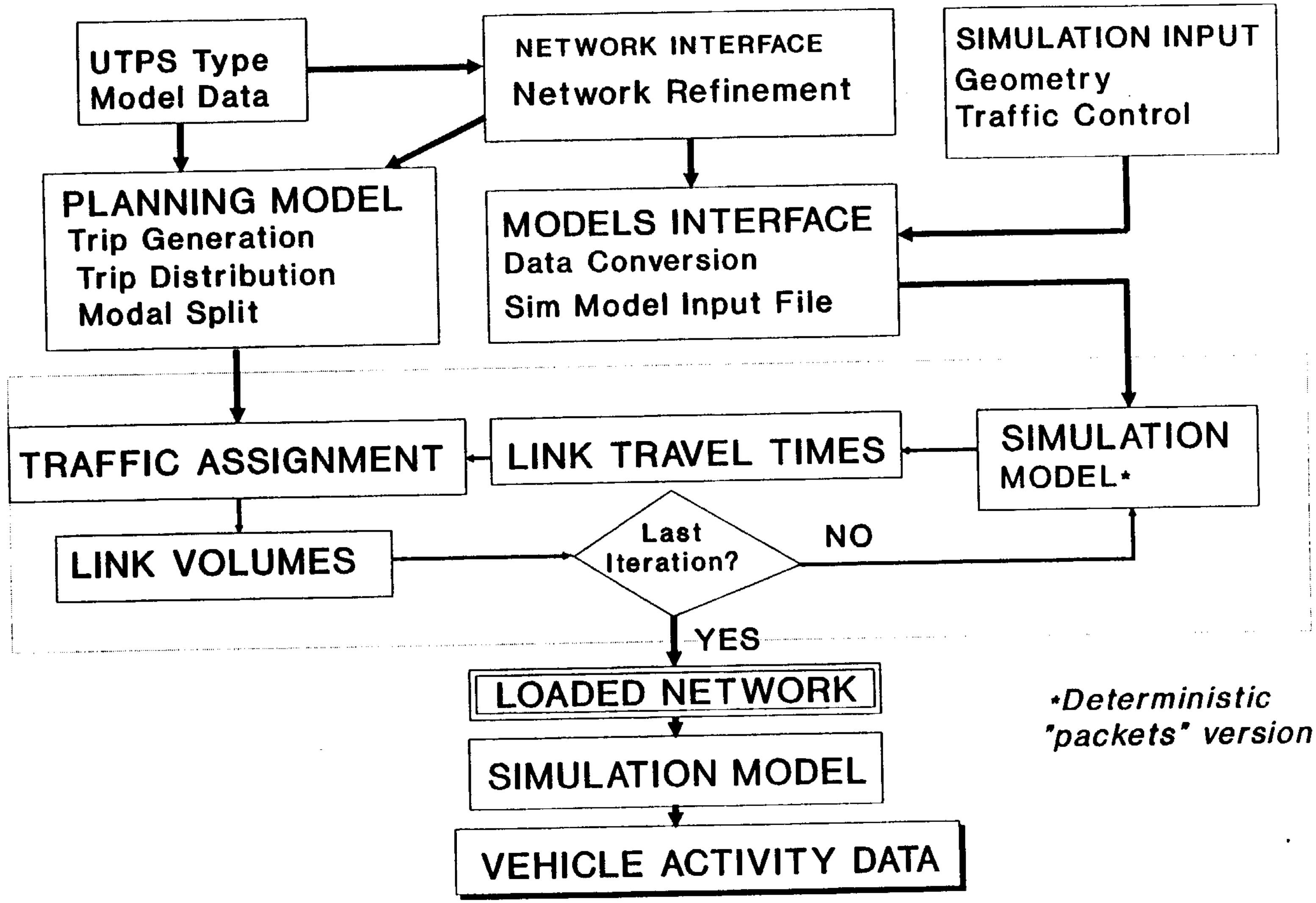
TRAF-NETSIM and FRESIM are stochastic models and use random numbers to assign driver/vehicle characteristics (e.g., free flow speeds, start-up delay, gap acceptance, etc.). Therefore, the performance data may vary for different sequences of random numbers under the same network characteristics. Repeated simulation runs should be made to gauge these stochastic effects. Experience from model runs in several studies indicated that difference in traffic performance of about 3 percent for undersaturated networks are due to the stochastic variability of the models, and not to the alternatives tested. NETSIM does provide the option to use "identical" traffic streams in model runs, i.e., same sequence and characteristics of generated vehicles, to reduce the variance in the model runs. The results would also vary with the length of the simulation run. This variability could be estimated through several runs with different simulation times. For undersaturated conditions, stable results are normally obtained for 30 minute long simulations. Oversaturated conditions may require multiple computer runs with different traffic volumes in each time slice to obtain reliable results.

3.2 UTPS Post-Processor II (Modification of the Assignment Algorithm)

This approach shown in Figure 3.2 is similar to the previous model formulation regarding the model interfaces, data requirements and model outputs. The major difference is that the simulation models are used in the assignment step of the planning model. The travel speeds predicted by the simulation model would be fed back to the assignment algorithm of the regional model to refine the link volumes and speeds. The process would continue until convergence is achieved and final link volumes are obtained. The simulation models would then run to produce vehicle activity data. This approach would improve the assignment process because it explicitly considers queuing on the network links, and the vehicle interactions with the link characteristics instead of using the speed-flow relationships in MINUTP.

The key issue with this model formulation is the computational requirements for multiple microscopic simulations of large scale networks. A number of options were investigated to develop a computationally feasible procedure:

FIGURE 3.2 UTPS POST-PROCESSOR II MODEL



Parallel processing: the assignment and simulation functions will be performed in parallel. This approach is employed in developing the ATMS model and has been used in a project within the European DRIVE Program for advanced technologies. It requires acquisition of special purpose computers, although it could be possible to perform parallel processing computations on conventional office workstations connected to a local area network. However, any implementation would require extensive software modification in the existing models which is beyond the resources and scope of this project.

Probe vehicles: Selected vehicles would act as probes inside the simulation model, and their speeds (travel times) would be used as input to the assignment algorithms. When the traffic assignment has been completed, then a complete simulation will be performed to derive performance measures for the entire network. INTRAS and TRAF-NETSIM, however, cannot model tagged vehicles and accumulate their statistics. Also, the accuracy of the travel speeds would depend on the specified number of probes, which is largely network specific.

Special simulation model: Modification of the NETSIM and INTRAS models for faster execution times to predict the travel speeds for the traffic assignment. Thorough examination of the computational performance of the microscopic models at the subroutine level indicated that most of the computational resources are consumed in the generation and assignment of attributes of each vehicle through stochastic processes and the updating of their position at each time step. Based on the analysis of several model modifications, simulating "deterministic packet of vehicles", similar to the CONTRAM model, appears to produce promising results in reasonable computer costs. The modifications to obtain such a special version of the TRAF-NETSIM and INTRAS models would include:

- Generation of vehicle packets: the model would generate and simulate "packets" of vehicles (i.e. a single vehicle generated would have the performance and size characteristics of 10 regular vehicles). For example, the model could then simulate 1,000 vehicles at the memory and execution time requirements of only 100 vehicles.

- Inhibit stochastic features: all the simulated "vehicles" would have identical driver/vehicle characteristics, i.e., the stochastic generation of attributes will be inhibited. This modification would be implemented in the vehicle generation routines to disable the use of random numbers to assign driver/vehicle characteristics. The results from sample NETSIM runs indicated that the link speeds using this option differ by about 5 to 8 percent compared to the predictions from stochastic simulations, which would be acceptable for feedback to the planning model. The model would still simulate in detail the interactions between vehicles, design characteristics and traffic control, as well as the queue formation and decay on the network links.

- Increased time-step: coarser resolution in the vehicle updating within the simulation. The vehicles' position, speed and acceleration will be updated every 2 sec instead of the default 1 second resolution. This would involve modifications in the models' book-keeping (CLNUP) routines.

- Output routines: Elimination of all the accumulation and processing of the link performance data except the travel times needed for the traffic assignment.

- Warm-up period: The simulation models use a time period to fill the network with vehicles before the accumulation of output statistics. This warm-up (fill-in) period is normally equal to the time needed to travel through the network under free flow conditions. To avoid having warm-up periods for each run during the iterative process for traffic assignment, the model would be modified to store a loaded network at the end of the simulation run.

- Input coding modifications: The link-node structure will be modified to exclude interface links and nodes in the boundary of the network for accumulating output statistics. Also, any traffic responsive control will be coded as the "equivalent" fixed-time to reduce the programs' running time.

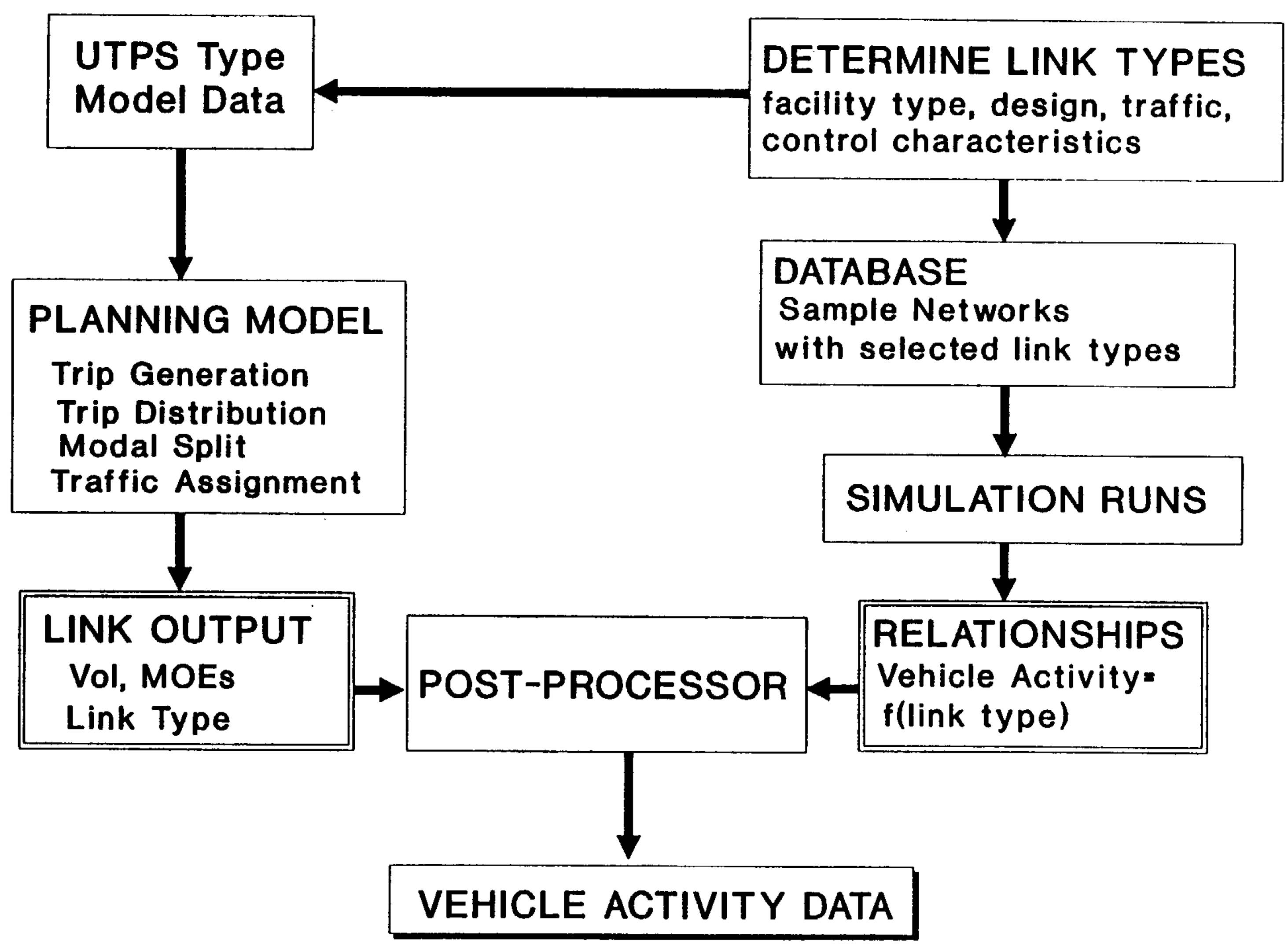
The modified version of the simulation models will be used to determine the speeds for the traffic assignment. Following the determination of the link volumes, the full scale NETSIM and INTRAS models will be executed to produce vehicle activity data.

3.3 The Sampling Approach

This approach illustrated in Figure 3.3 does not involve the direct linking of the regional and simulation models. Instead, the simulation models will be used to develop relationships between the basic link characteristics and vehicle activity. These relationships will be incorporated in a specially written post-processor to the planning model. The output from the planning model will provide estimates of VMT, travel time, volume and v/c for each link type. These data will be input to the post-processor to obtain vehicle activity data for each link and the total network.

The network links are stratified into a number of distinct link types depending on facility type, design, traffic and control characteristics. For each designated link type vehicle activity data will be generated for different combinations of link design characteristics, traffic patterns and traffic control through microscopic simulation on small scale networks with the selected link types. The analysis of the simulation outputs would produce a set of relationships which determine the time spent T_j on a network link in driving mode j as follows:

FIGURE 3.3 THE SAMPLING APPROACH



$$T_{ij} = F\,(link\ type,\ v/c) \qquad (3\text{-}1)$$

where:
Link Type: link classification based on the design, traffic and control characteristics
v/c: volume to capacity ratio

3.3.1 Determination of Link Types

It is important that sufficient number of link types should be designated to capture the variation of the characteristics in the different highway facilities commonly found in the field. Table 3.2 shows possible criteria to be used for link classification for the facility types commonly employed in the coding of networks for the regional models.

The process for determining link types is illustrated through the following example. Consider the case of arterial streets. Typical parameters to be considered and their range of values to determine link types for arterials are shown in the table below:

PARAMETER	RANGE OF VALUES
Location	urban, suburban
No. of through lanes	2, 3/4
Turning lanes	yes, no
Cruise speed	25,35,45
Turning traffic (%)	10,15,20
No of signals/mile	2,4,6
Signal phasing	protected LT, perm. LT
Signal progression	good, uncoordinated, poor

The combination of all these parameters would result in 1296 separate link types for arterials for which would be infeasible to determine relationships and code them in the model. An alternative approach is to employ the methodology of arterial segment classification adopted in the 1985 Highway Capacity Manual (Chapter 11--Arterials) (37):

- Class 1: *suburban high design facilities with multilane approaches, exclusive left turn lanes, protected phasing, and speeds of 40-45 mph.*
- Class 2: *urban/suburban, 2-3 lanes per approach, some intersections with no turning lanes, and free flow speed of 30-35 mph.*
- Class 3: *urban settings (shared lanes, permitted phasing, short spacing), and free flow speed of 25-30 mph.*

and then use the quality of signal progression as a surrogate for traffic control, i.e., i) good (less than 40 percent of vehicles stopping at the intersection approach), ii) uncoordinated (about 40-80 percent stopping) and iii) poor (about 80 percent stopping). This approach would result into only nine separate link types.

TABLE 3.2 POSSIBLE CRITERIA FOR DETERMINING LINK TYPES

FACILITY TYPE	CLASSIFICATION CRITERIA
Freeways	Section Type Straight section Merging Weaving Design Characteristics Number of lanes Lateral clearance Design speed
Expressways	Design Characteristics Location Free Flow Speed Number of Lanes
Arterials	Design Characteristics Location (urban/suburban) Number of through lanes Turning lanes/pockets Number of signals/mile Free flow speed Traffic Characteristics Proportion of turning traffic Ratio of through/cross-street traffic Control Characteristics Signal phasing Controller type Quality of progression
Ramps	Design Characteristics On vs. off-ramps Number of lanes Design speed Configuration (loops .vs. straight) Control Characteristics Metering
Collectors	Design Characteristics Number of through lanes Turning lanes/pockets Control Devices Signals Stop Signs

The above example illustrates that it is practically impossible to consider all the variations in the characteristics of highway facilities into separate link types and develop vehicle activity estimates. Therefore, the sampling approach would have to consider only a subset of conditions represented in the field. The final determination of link types to be considered in the methodology was based on the accuracy of the relationships, time and computational resources to develop the relationships, data collection/coding requirements to implement this approach in the planning model, link types coded in the MTC model (shown in Table 3.4), and overall cost-effectiveness. The proposed link types for developing the relationships are shown in Table 3.3.

TABLE 3.3 PROPOSED LINK TYPES FOR DEVELOPING RELATIONSHIPS

FACILITY TYPE	CLASSIFICATION CRITERIA	RANGE OF VALUES	#LINK TYPES
Freeways	Section Type No of lanes Design Speed	Simple section/ merging,weaving 6,8,10 60,70	12
Expressways	Free Flow Speed No of lanes	50,60,70 4, 6/8	6
Arterials	Arterial class Progression quality	I,II,III poor, uncoord,good	9
Ramps	No of lanes Configuration Metering/signal	1, 2 on-, -off yes, no	8
Collectors	No of lanes Traffic control	1, 2 stop sign/signal	4
TOTAL			39

3.3.2 Development of the Relationships

The relationships between time-spent in each mode and link types would be derived from the analysis of the vehicle activity data generated through simulation on sample networks. Therefore, it is important that the data bases to be used consist of real-life networks that include all the proposed link types. Furthermore, the process may require an extensive amount of computer runs. Referring again to the previous example for arterials, to obtain estimates for link type 1 (suburban arterial with good progression) it would require a minimum of 11 runs for a range of v/c values from 0.1 through 1.1 and

TABLE 3.4 LINK TYPES IN THE MTC MODEL (Source Ref. 23/MTC Network)

AREA TYPE	FACILITY TYPE							
	Frw-to-Frw (1)	Frw (2)	Expwy (3)	Collector (4)	Ramp (5)	Dummy (6)	Major Art (7)	Metered Ramp (8)
Core (0)	1700	1850	1300	600	1300	2000	850	700
	40	55	40	20	30	100	25	25
CBD(1)	1700	1850	1300	600	1300	2000	850	700
	40	55	40	25	30	100	30	25
UBD (2)	1700	1900	1450	650	1400	2000	900	800
	45	60	45	30	35	100	35	30
Urban (3)	1750	1900	1450	650	1400	2000	900	800
	45	60	45	30	35	100	35	30
Suburban (4)	1800	1950	1500	800	1400	2000	950	900
	50	65	50	35	40	100	40	35
Rural (5)	1800	1950	1500	850	1400	2000	950	900
	50	65	55	40	40	100	45	35

Upper Entry: Capacity (vphl)
Lower Entry: Free-flow speed (mph)

at least 7 replications for a total of 77 computer runs. This indicates that about 700 model runs would have to be performed for the proposed link types shown in Table 3.3 assuming that each link is simulated independently. However, the number of computer runs would be reduced substantially through careful selection of test sites to include a range of link types and v/c ratios. For example, using seven arterial data sets consisting of a total of 80 links representing all the proposed nine link types and v/c ratios between 0.3 through 0.9 would require approximately 40 computer runs to obtain the model predictions to be used in the relationships. This discussion points out the importance of carefully selecting the sample data sets for the simulation experiments.

The analysis of the simulated vehicle activity data would employ basic exploratory data analysis and regression analysis techniques to determine the relationships between time-spent and link types. The process will also examine the significance of the differences in the relationships between different link types. The analysis of the results will also take into consideration the stochastic variability in the simulated model output as discussed in section 3.1.3.

3.4 Evaluation of the Alternatives

The three approaches for the integrated model were evaluated considering the accuracy of their predictions, range of applications, data input and coding requirements, software modifications, computational resources, and overall cost-effectiveness. The findings from the evaluation are presented below:

Accuracy of the Estimates: The UTPS Post-Processor I approach of sequentially linking MINUTP with operations software has been implemented in a number of studies and the major weakness is that the volumes from the planning model are unrealistically high especially for turning movements on the surface streets (10). This is because MINUTP does not consider queuing and other factors in the assignment. This would result in inaccurate estimates of the total travel time spent in each mode. The UTPS Post-Processor II model would overcome this deficiency and improve the accuracy of the assigned volumes because it involves the use of the simulation output in the assignment process.

The sampling approach has the same limitation as the Post-Processor I model regarding the output from the planning model. The only direct approach is to incorporate queuing analysis in MINUTP which is outside the scope of the study. An alternative approach would be to replace the default BPR equation used in the assignment by speed-flow relationships specific to each link type coded. This information will be provided by the simulation models through the process of generating vehicle activity data for the entire range of traffic loadings (v/c.) The network simulation models provide directly the average speeds (travel times) so it would be relatively straightforward to determine speed-flow relations per link type. Finally, the queuing post-processor approach (6) would be also used to improve the results of the assignment.

Range of Applications: The UTPS Post-processor models are best suited for subarea analysis, not for simulating entire regions. First, it's impractical to simulate the entire Alameda County network, to estimate changes in emission levels due to ramp metering scheme along the I-80 in the vicinity of the city of Berkeley, or due to signal timing improvements in the city of Pleasanton. Secondly, it is computationally infeasible to simulate the entire County at the level of detail of microscopic models. The typical use of such models is to test the effectiveness of selected measures through the following steps:

(1) Apply the regional demand model and obtain the trip table
(2) Perform a subarea analysis to refine the network specific to the measures being evaluated
(3) Run the proposed integrated model
(4) Obtain modal activity data for the subarea
(5) Check for consistency between the subarea analysis and regional model, i.e., feedback to the regional model.

Vehicle activity data for the entire region can be obtained from the extrapolation of the data from the subarea analysis, which would be at best an approximation. The underlying assumption is that the proportion of the time-spent in each mode on a facility in the subarea being modeled will be the same for the same type of facilities in the rest of the region.

The sampling approach readily produces regionwide estimates of vehicle activity data because it is an extension of the regional model. However, this approach cannot evaluate directly measures for emission reduction for particular locations or corridors because it would estimate the changes using an average rate of modal activity data where the selected measures may introduce quite larger changes.

Data Requirements: Both UTPS Post-Processor type models require a refined network and the input data as shown in Table 3.1. Most of the operational data (geometrics, traffic control) are readily available in the responsible public agencies' offices or could be easily collected in the field. The effort required to collect all the data for simulation models excluding traffic counts is estimated at about 1 hour per intersection. The largest effort, however, is the recoding of the network in sufficient detail for the microscopic models. The sampling approach does not require recoding of the network except of coding additional fields in the link data file identifying the "link types." This process would not have to be performed should the network has been already coded with sufficient number of separate link types (area type/facility types) that correspond to the proposed link types (example the link types in the MTC model--Table 3.4.) The determination of the link types could be based on existing data and sample field surveys. This process could potentially introduce inaccuracies because of judgmental errors, e.g., classifying a link type with good signal progression where in fact this may be true in only one direction of the link.

Computational resources: The UTPS Post-Processor models are computationally intensive and would require mainframe computers for efficient applications. Although recently TRAF-NETSIM simulation of a large portion of the city of San Francisco has been implemented in an office workstation, larger applications would require mainframes. This is especially true for the Post-processor II model which involves repeated network simulations. The sampling approach is certainly computationally feasible because simulations will be performed on sample networks and its implementation would be a post-processor to the planning model, so it would run on the same platform as MINUTP (3/486 based PC microcomputers.)

Software development: All of the approaches require modification of the simulation models output routines to determine the time-spent in each mode from the simulated vehicle trajectories. The UTPS Post-Processor type models require significant changes including developing model interfaces and resizing of the program arrays to handle large networks. The UTPS Post-processor II model in particular requires the most extensive software modifications because it involves creating a special version of the microscopic models to estimate travel times for the traffic assignment. The sampling approach requires writing a post-processor to the planning model which is fairly straightforward.

The objective of this study is to develop a modeling system to produce accurate regionwide estimates of vehicle activity and at the same time be used in practice. The evaluation of the alternative approaches for the integrated model shows that the sampling approach has the highest cost-effectiveness. However, it is important to recognize that the continuous technological advancements and automation in data acquisition and transfer would make integrated models of Post-Processor II type a reality for entire regions. Therefore, the sampling approach has been selected for developing an integrated modeling system and demonstrate its application in the entire MTC Bay Area network. Recommendations would be also provided for a study design to develop a computationally efficient UTPS post-processor II type model.

CHAPTER 4

DEVELOPMENT OF THE MODEL

This Chapter describes the development of the proposed integrated model based on the sampling approach. The process for model implementation is illustrated in Figure 4.1. The following steps were undertaken:

(1) Write software to calculate the time-spent in each driving mode from the vehicle trajectories produced as part of the output of the simulation models.

(2) Select sample networks for freeways and surface streets. Classify the links in each network into link types based on the criteria described in Table 3.3.

(3) Perform INTRAS and TRAF-NETSIM simulation runs for the selected sample networks. Obtain vehicle activity data for each link type.

(4) Analyze the simulation results to develop relationships between link types and time-spent in each driving mode.

(5) Incorporate the relationships into a post-processor to the MINUTP model to estimate the time spent in cruise, acceleration, deceleration and idle modes from the output of the regional model.

4.1 Simulation Output Processing Routines

The TRAF-NETSIM and INTRAS models have the option to store in a file the trajectories of vehicles as they travel through the network during the simulation run. The data stored in each file record consist of the clock time, link number, vehicle type and the vehicle's position, speed and acceleration. The data are packed into 4-byte words before written to the file. Information on the data packing and format of the records in the trajectory file was obtained from the programs' source code and documentation. A number of recent changes to the models, however, were not documented and several contacts had to be made with the FHWA staff and their consultants responsible for the software maintenance to obtain the latest versions of the models' source code.

Routines were written in Microsoft FORTRAN to read the information from the trajectory file, calculate the time spent per driving mode for each link, and summarize the results for the network. The programs were debugged and verified using the distance travelled, average speed, idle time and moving time provided directly by the simulation models outputs. Figure 4.2 shows the sample output from the TABLE4 program used to process the trajectory file from the TRAF-NETSIM version 4 model. The listing of the program is included in Appendix G.

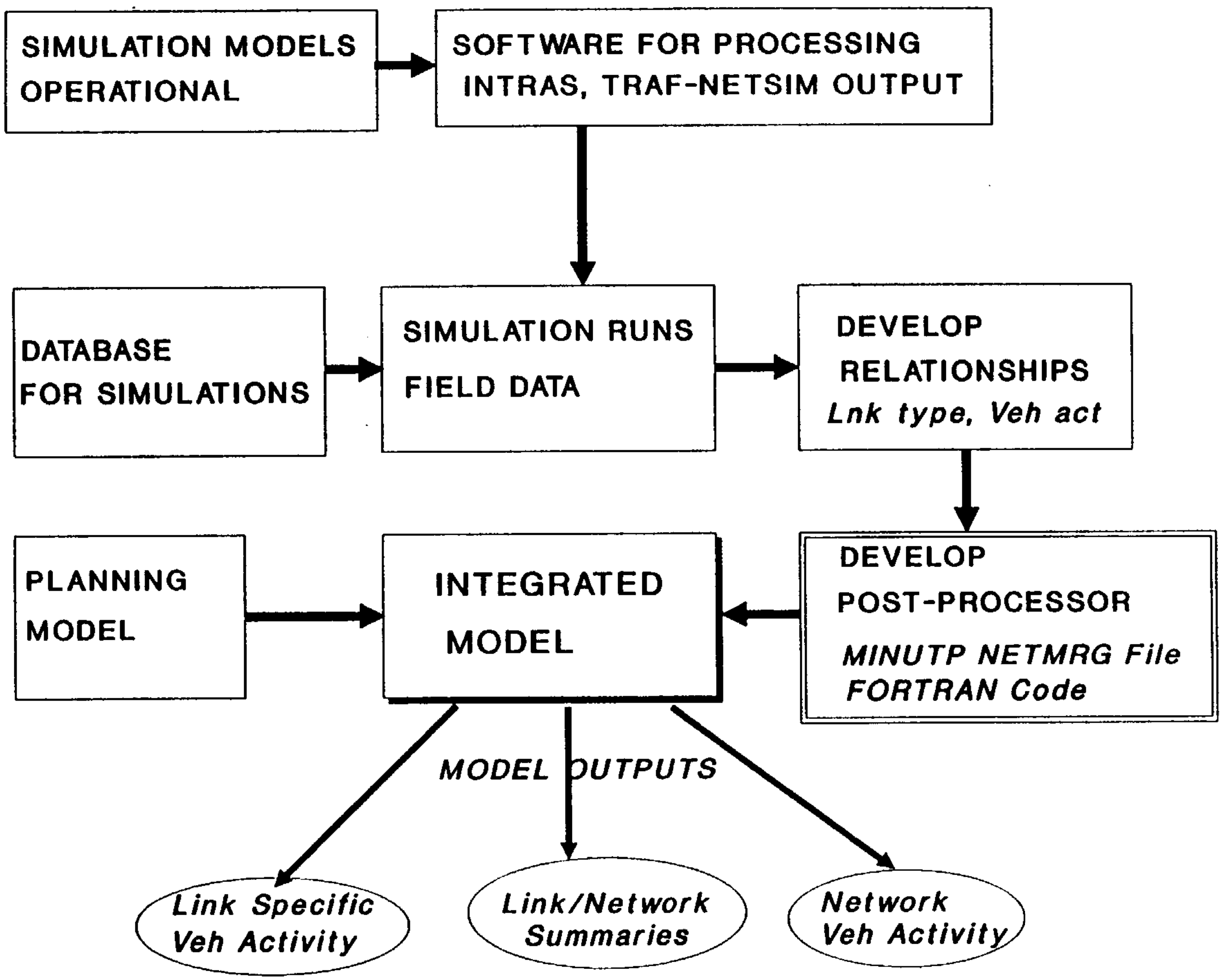


FIGURE 4.1 PROCESS FOR INTEGRATED MODEL DEVELOPMENT

FIGURE 4.2 OUTPUT FROM THE PROCESSING OF THE TRAF-NETSIM TRAJECTORY FILE

"TOTAL LINKS=" 29"Total Veh-Secs=" 53157"Mean Speed 100ths of FPS=" 2159
"Vehicle-Seconds by speed (MPH) (row) and acceleration (MPH/SEC) (col)"

"mph"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7
0	0	0	0	0	0	0	0	18232	0	0	2	0	96	3	0
5	0	0	148	11	3	646	309	393	330	143	221	71	324	13	0
10	0	0	40	76	195	517	232	487	338	165	271	323	163	60	0
15	0	0	40	279	229	363	150	384	188	89	449	222	62	102	0
20	0	0	53	407	126	424	173	321	246	293	1049	20	12	91	0
25	0	0	41	302	130	383	213	914	1290	741	306	3	1	13	0
30	0	0	67	185	109	348	433	5625	4154	463	30	1	1	3	0
35	0	0	23	69	33	132	176	3541	2566	48	2	0	0	0	0
40	0	0	4	4	10	21	18	528	441	0	0	0	0	0	0
45	0	0	0	1	2	1	3	109	85	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.2 The Data Base

A large and comprehensive data base for freeways and surface street networks was assembled from past studies by the research team and other sources. These test sites are described below:

The FHWA data sets (Table 4.1): fourteen real-world data sets on urban arterials and grid networks representing a wide range of geometric, traffic and control conditions as well as national representation. These data have been assembled and coded for the NETSIM model as part of a DHS study on Progression Through a Series of Intersections with Traffic Actuated Controllers sponsored by FHWA (34) and have been used in several other FHWA research projects.

The FETSIM Program Data Base (Table 4.2): data from several local agencies on urban arterials and networks are available from the California's Fuel Efficient Traffic Signal Management (FETSIM) Program. One FETSIM research study carried out by the research team used eight real-world data sets from California cities to test the effectiveness of alternative control measures through simulation (Table 4.2). These test sites cover a wide range of conditions from dense downtown grids (Berkeley CBD) to suburban widely spaced arterials/expressways (Air Base Parkway in Fairfied), and are coded for an old version of the NETSIM model.

TABLE 4.1 FHWA SURFACE STREETS DATA SETS

TEST SITE	LOCATION	# OF SIGNALS	# OF LANES	SPEED (mph)	# PHASES 2	4	8	CYCLE (sec)
I. ARTERIALS								
1. EL CAMINO REAL	Redwood City, CA	8	6	33	0	7	1	100
2. FANNIN BLVD	Houston, TX	15	6/8	35	4	10	1	90
3. MICHIGAN AVE	Chicago, IL	11	6/8	30	10	1	0	90
4. M STREET	Washington, D.C.	8	4/6	30	5	3	0	60
5. NICHOLASVILLE RD	Lexington, KY	12	6	35	0	8	4	90
6. UNIVERSITY AVE	Provo, UT	10	6	30	1	9	0	80
7. YGNACIO VALLEY	Walnut Creek, CA	12	8/10	38	0	8	4	124
II. GRID NETWORKS								
1. ANN ARBOR CBD	Ann Arbor, MI	28	6/8	25	27	1	0	65
2. DAYTONA BEACH	Daytona Beach, FL	12	4/6	25	5	4	3	100
3. MEMPHIS CBD	Memphis, TN	23	4/6	30	21	2	0	65
4. OGDEN CBD	Ogden, UT	19	6	30	19	0	0	70
5. POST OAK	Houston, TX	13	6	35	5	1	7	120
6. SILVER LAKE	Los Angeles, CA	15	4/6	25	2	9	4	90
7. WALNUT CREEK	Walnut Creek, CA	23	6/8	25	14	5	4	100

TABLE 4.2 THE FETSIM HARDWARE STUDY DATA BASE

TEST SITE	LOCATION	# OF SIGNALS	# OF LANES	SPEED (mph)	# PHASES 2	4	8	CYCLE (sec)
I. ARTERIALS								
1. Air Base Parkway	Fairfield, CA	6	6	50	0	6	0	100
2. El Camino Real	Redwood City, CA	8	6	35	0	7	1	100
3. San Pablo Ave	Berkeley, CA	11	6	33	11	0	0	70
4. Ygnacio Valley Rd	Walnut Creek ,CA	12	8/10	38	0	8	4	124
II. GRID NETWORKS								
1. Berkeley CBD	Berkeley, CA	10	4/6	25	10	0	0	70
2. Concord CBD	Concord, CA	11	4/6	25	4	5	2	75
3. Hayward CBD	Hayward, CA	12	4/6	25	12	0	0	60
4. Walnut Creek CBD	Walnut Creek ,CA	14	6/8	25	7	3	4	90

NOTES

1. # of lanes include left-turn lanes

2. SPEED: free-flow speed

3. 4-phase signals refer to protected LT phases on one street only (it includes 3 phase signals on one-way cross str)
8 phase signals refer to protected LT phases on all intersection approaches

4. Cycle length for coordinated signal operation

The I-80 Corridor (Figure 4.3): This test site consists of an eight mile section of the I-80 freeway and the San Pablo Avenue parallel arterial. It extends from the Powell Street exit in the city of Emeryville to the Barrett Avenue exit in the city of Richmond. Data for the freeway include geometrics, ramp and mainline counts for the peak periods and travel time and delay runs. Information for San Pablo Avenue (Table 4.3) includes turning movement counts, intersection geometrics and signalization. The data have been coded for the FREQ and TRANSYT macroscopic models. Also, some segments of the San Pablo Ave have already been coded for TRAF-NETSIM. The data have been recently verified and updated as part of simulating the corridor with the INTEGRATION models to test advanced control strategies for urban networks (32).

FIGURE 4.3 THE I-80 CORRIDOR

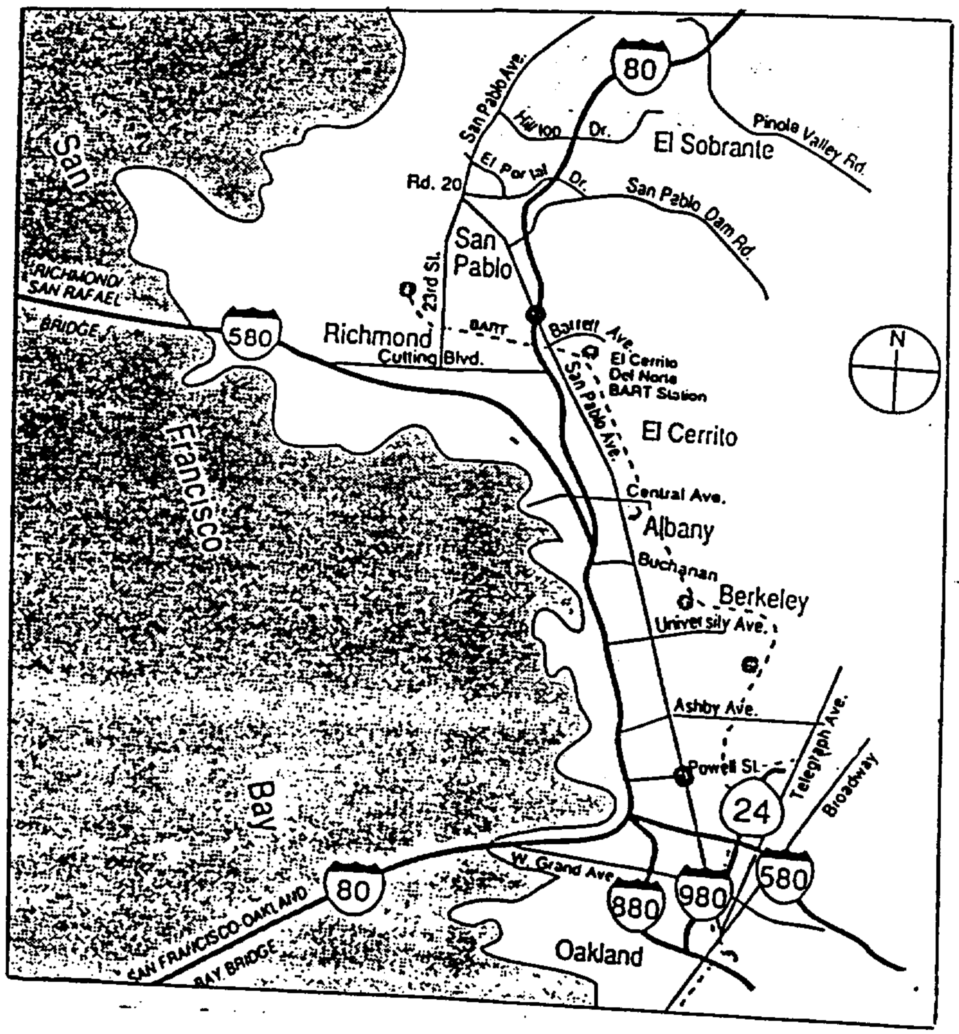


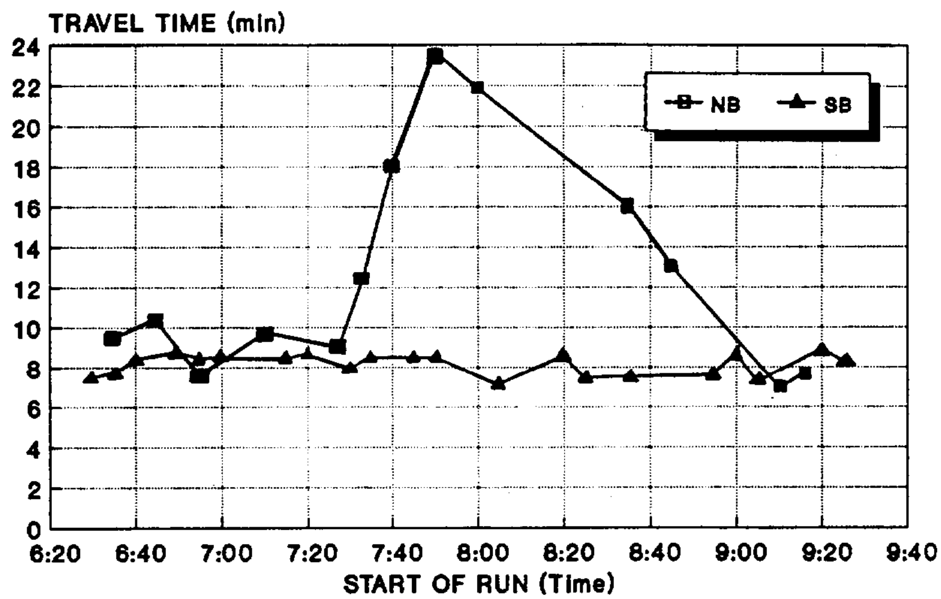
TABLE 4.3 THE SAN PABLO AVENUE DATA SET

SIG #	CITY	STREET NAME	SPACING (ft)*	T-INT	# LANES CROSS STREET**	SIGNALIZATION		
						P/A	PHASES	CYCLE
1	OAKLAND	STANFORD			2(1)	P	2	60
2		ALCATRAZ	2280	X	1	P	2	60
3	BERKELEY	ASHBY	1943		3(1)	P	2	80
4		GRAYSON	1631	X	1	P	2	80
5		DWIGHT WAY	1835		2	P	2	70
6		ALLSTON WAY	1980		1	P	2	70
7		ADDISON	520	X	1	P	2	70
8		UNIVERSITY	450		3	P	2	70
9		DELAWARE	977		1	P	2	70
10		CEDAR	1300		3(1)	P	2	70
11		GILMAN	1983		2	P	2	70
12	ALBANY	MARIN	2380		2(1)	A	4	90
13		BUCHANAN	400	X	1	A	2	90
14		SOLANO	420		2	A	4	90
15		WASHINGTON	790	X	1	A	2	90
16		CLAY	1410	X	1	A	2	90
17		BRIGHTON	240	X	2	A	2	90
18	EL CERRITO	CARLSON	870		3	A	4	80
19		FAIRMOUNT	630		2(1)	A	4	80
20		CENTRAL	630		3(1)	A	4	80
21		STOCKTON	2190	X	1	A	4	80
22		MOESER	1470	X	2	A	4	80
23		SCHMIDT	1150	X	2	A	4	80
24		MANILA/BAYVIEW	720		1	A	4	80
25		PORTRERO AVE	2070		3(1)	A	4	80
26		HILL/EASTSHORE	1230		3(1)	A	4	80
27		CUTTING BLVD	760		4(2)	A	6	80
28	RICHMOND	McDONALD AVE	3000		3(1)	A	6	I
29		BARRET	1220		4(1)	A	6	I
30		ROOSVELT/EB I-80	620	X	3(1)	A	2	70

NOTES:
*xxxx: Distance to the previous signalized intersection
**X(Y): Total # of lanes on the critical approach (# of exclusive lt lanes)
P/A: Pretimed (fixed-time) signal/Actuated signal
4-phase: protected LT on the arterial
6/8 phase: protected LT on the arterial and the cross-streets
Cycle: Existing cycle length (I: signals operating uncoordinated)

I-880 Hayward (Figure 4.5): This is a seven mile section along the I-880 freeway between the SR238 interchange and the Industrial Parkway in the city of Hayward. This section has a range of design and operational features and is part of the cornerstone project for the Caltrans Bay Area Traffic Operations Center (BATOC). Loop detectors are installed every one third of a mile on each lane on the mainline, and on all the on- and off-ramps. A unique data collection effort has been recently completed as part of the evaluation of the freeway service patrols (FSP) (30). The data consist of speed, flow and occupancies from the loop detectors, vehicle trajectories from instrumented vehicles traveling the section at 5 min headways, and recordings of traffic incidents. The data were collected during the peak periods for 24 consecutive days "before" and "after" the implementation of the FSP. Figure 4.4 below shows the travel times of instrumented vehicles and Figure 4.6 shows sample data from the loop detectors.

FIGURE 4.4 FLOATING CAR TRAVEL TIMES
I-880 HAYWARD (Source: Ref 30)



The available data sets were carefully reviewed for consistency, completeness and representation of link type classification shown in Table 3.3. Twelve data sets for the surface streets were selected the simulation experiments (Table 4.4.) The selected surface street networks consist of a total of 111 intersections and 214 links. For the freeways, segments of both I-80 and I-880 were selected consisting of a total of 24 links (segments between on- and off-ramps.)

FIGURE 4.5 THE I-880 TEST SITE

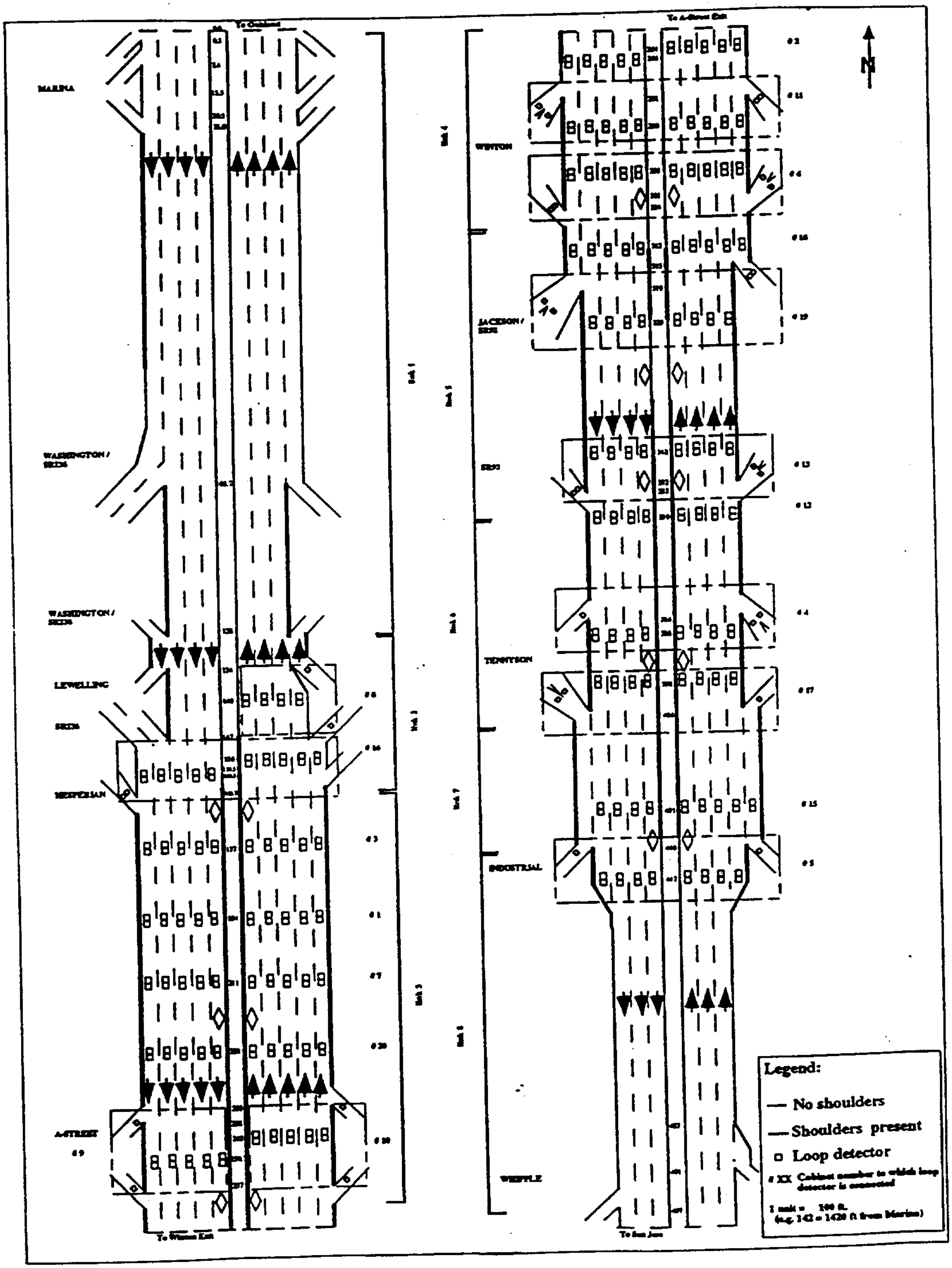


FIGURE 4.6 DATA FROM LOOP DETECTORS
I-880 HAYWARD (Source: Ref 30)

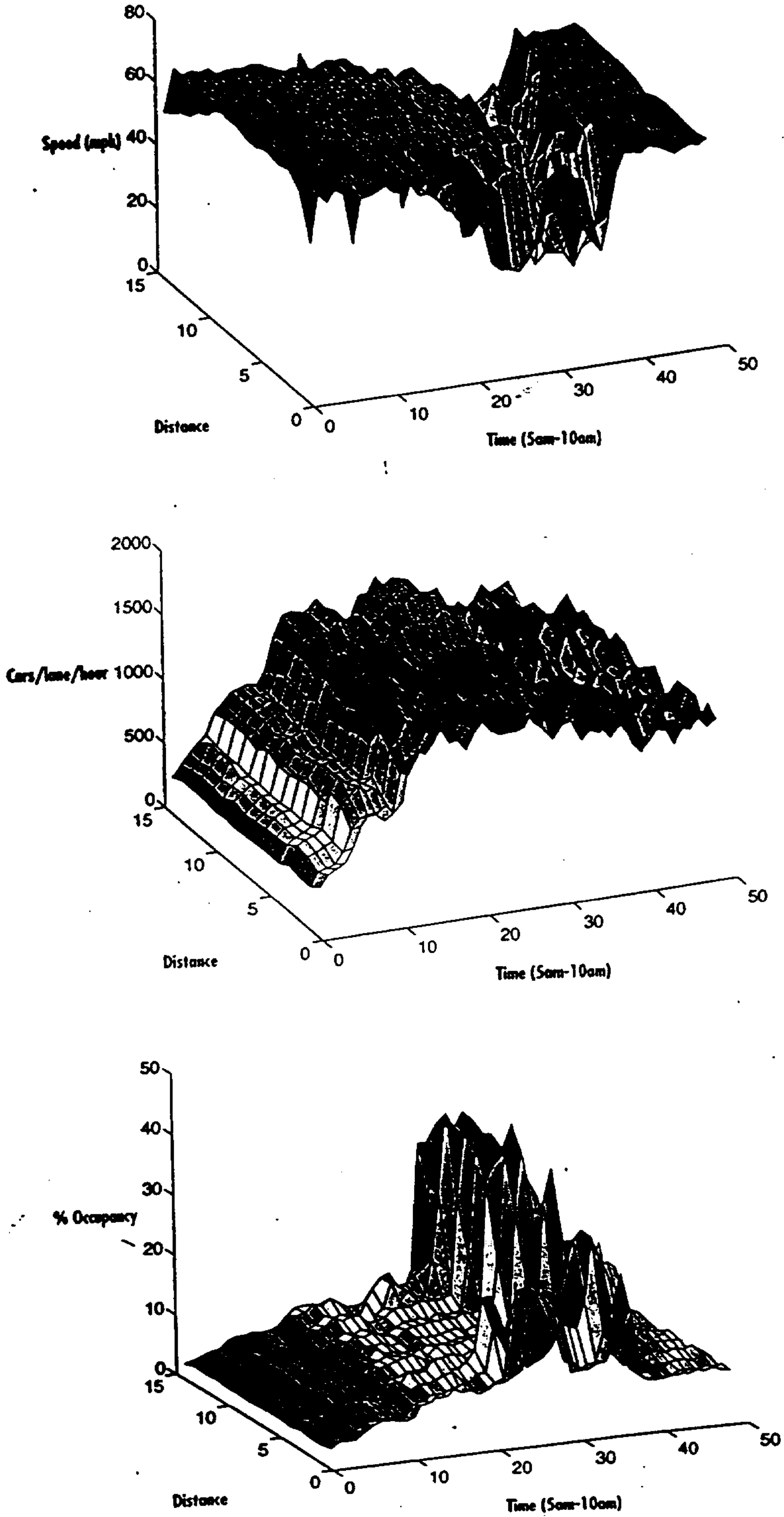


TABLE 4.4 SELECTED DATA SETS--SURFACE STREETS

TEST SITE	# OF SIGNALS	# OF LINKS	SPACING (ft) Range	SPACING (ft) Mean	# OF LANES	VOLUME (vph/l)	SPEED (mph)	# PHASES 2	# PHASES 4	# PHASES 8	CYCLE (sec)
I. ARTERIALS											
1. AIR BASE PKWY	6	24	3080 -5490	4554	6	873	50	0	6	0	100
2. EL CAMINO REAL	8	29	270 - 2070	868	6	1015	35	0	7	1	100
3. M STREET	8	28	295 - 935	502	4/6	783	30	5	3	0	60
4. NICHOLASVILLE RD	8	28	760 - 2160	1371	6	1062	40	0	8	0	90
5. SAN PABLO AVE A	8	30	450 - 1983	1292	6	1023	33	8	0	0	70
6. SAN PABLO AVE B	8	28	720 - 2070	1370	6	1040	35	0	8	0	90
7. YGNACIO VALLEY A	5	20	630 - 920	752	8/10	1208	30	0	1	4	120
8. YGNACIO VALLEY B	7	27	630 - 1990	1285	8/10	1196	40	0	6	1	120
II. GRID NETWORKS											
1. BERKELEY CBD	10	24	330 - 740	619	4/6	699	25	10	0	0	70
2. POST OAK*	11(18)	32(48)	450 - 2370	1347	6	948	35	5	1	5	80
3. SILVER LAKE	11	30	753 - 1593	1316	4/6	732	30	2	6	3	80
4. WALNUT CREEK	14	34	270 - 1040	617	6/8	558	25	8	3	3	90

NOTES

1. # of lanes include left-turn lanes(pockets)

2. VOLUME: the average critical lane volume at the intersection

3. SPEED: free-flow speed

4. 4-phase signals refer to protected LT phases on one street only (it includes 3 phase signals on one-way cross streets and T-intersections)
8-phase signals refer to protected LT phases on all intersection approaches

5. Cycle length for coordinated signal operation

**: The Post Oak network includes 7 two-way stop controlled intersections*

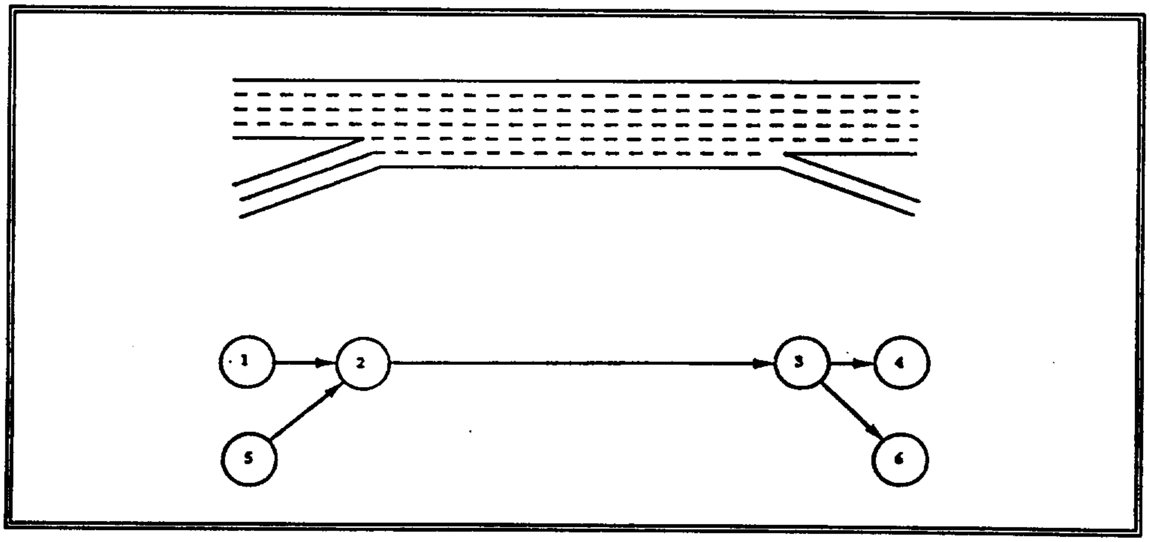
4.3 Simulation Runs

The selected data sets were first coded for the INTRAS and TRAF-NETSIM microscopic simulation models. A series of simulation runs were then performed to obtain the vehicle activity data and other traffic performance measures.

4.3.1 The INTRAS Model

The INTRAS model requires the coding of the freeway network into links and nodes. Links represent unidirectional traffic streams with homogeneous traffic and geometric characteristics, and nodes the locations where these characteristics change (e.g., merging or diverging areas). Figure 4.7 shows the coding of a typical freeway weaving section (33). In addition to the basic input data shown in Table 3.1, INTRAS requires information on length and location of acceleration lanes, grade and curvature, proportion of vehicle types in the traffic stream, and volume distributions per lane. The model predictions include total travel, travel time, volume, density, average speed, number of lane changes, delay, fuel consumption and emissions for each link at user specified time intervals during the simulation. Also, the program provides origin-destination specific volumes, travel times and speeds.

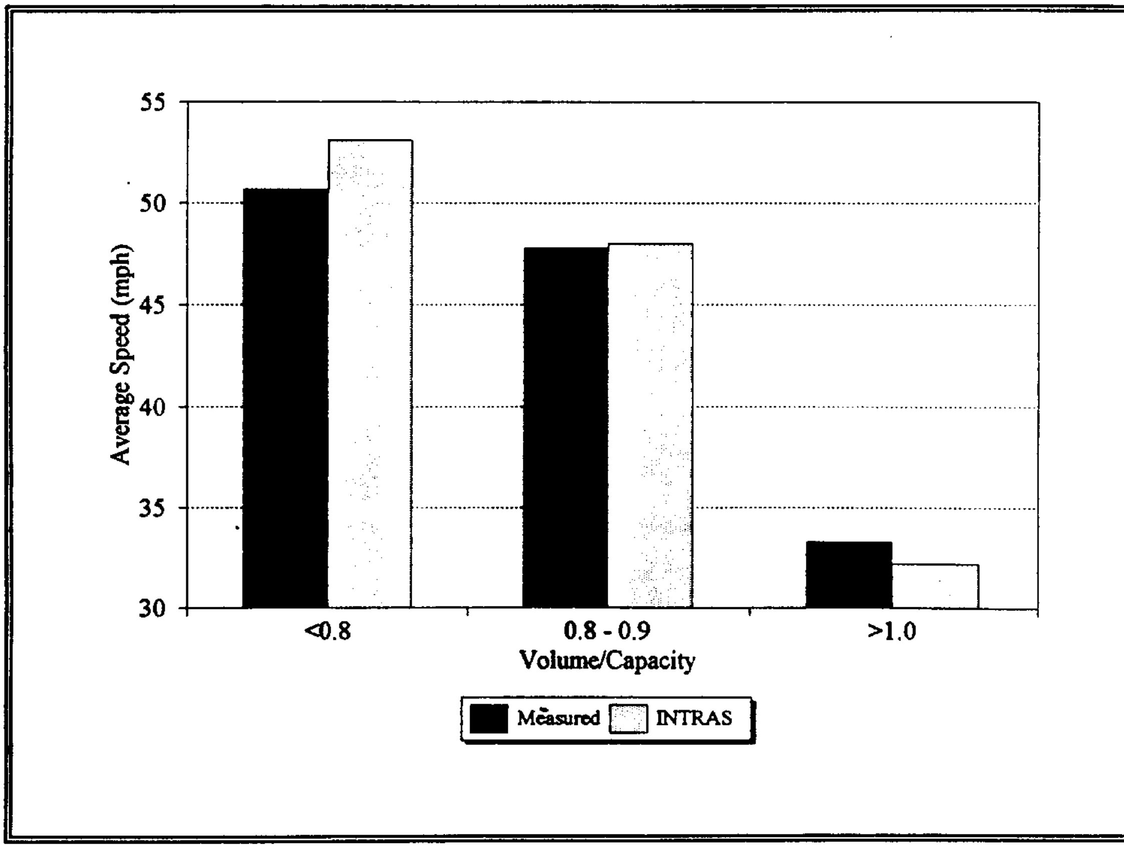
FIGURE 4.7 SAMPLE CODING FOR THE INTRAS MODEL



The coding the freeway networks into the model was a challenging process. INTRAS translates internally the user specified geometry by means of the lanes receiving traffic from the upstream to the downstream links. These lanes are coded using a lane numbering scheme. The model cannot deal directly with freeway segments including lanes drops and complex weaving sections with one lane on- and two lane off-ramps. The procedure to overcome this limitation was to code midblock "dummy" nodes and lanes feeding the downstream links in the merging and diverging areas. This process required several trial runs particularly for the I-880 test site due to the variations in design along its segments. Following the verification of the data coding, the calibration of the model involved adjusting several parameters to match observed conditions. These included the free-flow speed distributions per each lane, and driver sensitivity factor (a parameter in the car-following model related too the drivers' aggressiveness). The location of the warning signs for freeway exits was another important parameter for accurate modeling of weaving and diverging sections. Vehicles wishing to exit shift to the appropriate lane beginning at the location of the specified warning sign. The model allows only one lane change per each second of simulation, so vehicles would miss their desired exits if the warning signs has not been placed correctly and the predicted performance measures would be inaccurate. The locations of the warning signs were specified based on the number of lane changes, predicted volume distributions per lane and number of vehicles missing their exits warning output.

The aggregate and link specific model results on lane volumes, travel times and speeds were compared with field measurements. Figure 4.8 shows the measured and simulated travel speeds along the I-880 test site. The comparisons of simulated and measured data indicate that the model closely replicates observed conditions.

FIGURE 4.8 I-880: COMPARISON OF MEASURED AND SIMULATED SPEEDS



Next, a series of simulations were performed to obtain the time spent in each driving mode. The results were tabulated and analyzed separately for each link and for the entire network. Analyses were then performed to determine significant differences in vehicle activity between the designated link types for a range of traffic conditions. Table 4.5 shows the summary simulation results for two freeway link types as a function of volume/capacity ratio(v/c): i) simple freeway segments ("straight-pipe" sections) and ii) weaving sections. These results indicate that vehicle activity remains the same on straight-pipes for a wide range of traffic loadings. The proportions of time spent in cruise, acceleration, deceleration and idle modes were within 2 percent with minimal "stop and go" activity. When demand reaches or exceeds capacity, however, there is a significant change in vehicle activity with increase in stop and go travel and reduction in the average travel speed. These results are in agreement with the field data available and other recent studies reporting that speeds remain constant up to capacity conditions on urban/suburban freeways with significant commute traffic.

Weaving sections have different vehicle activity patterns than the simple freeway segments except for low traffic volumes. The results indicate considerably higher proportions of accelerations, decelerations and idling even for uncongested conditions. Typical weaving sections (as shown in Figure 4.7) are characterized of complex vehicle interactions and intensive lane changing maneuvers that must be performed in a limited area. They often form the bottleneck in a freeway system, and their capacity and operation depends on the section configuration and geometrics (number of lanes, section length) and the distribution of weaving and non-weaving vehicles.

TABLE 4.5 VEHICLE ACTIVITY PREDICTED ON FREEWAYS

	TIME SPENT (%)				AVERAGE
V/C RATIO	CRUISE	ACCEL	DECEL	IDLE	SPEED (mph)
Straight-pipe Sections					
0.5	55.9	22.7	21.2	0.2	57.4
0.75	54.6	23.6	22.4	0.4	55.7
.9	53.2	23.7	22.7	0.5	54.3
>1	34.6	31.0	26.5	7.7	32.3
Weaving Sections					
0.5	53.0	23.9	22.7	0.5	53.9
0.75	49.7	24.9	24.6	0.8	49.1
.9	42.1	27.5	28.8	1.6	36.9
>1	29.9	32.3	27.2	10.5	25.4

Figure 4.9 show the speed and acceleration distributions for basic freeway sections as a function of the volume/capacity ratio.

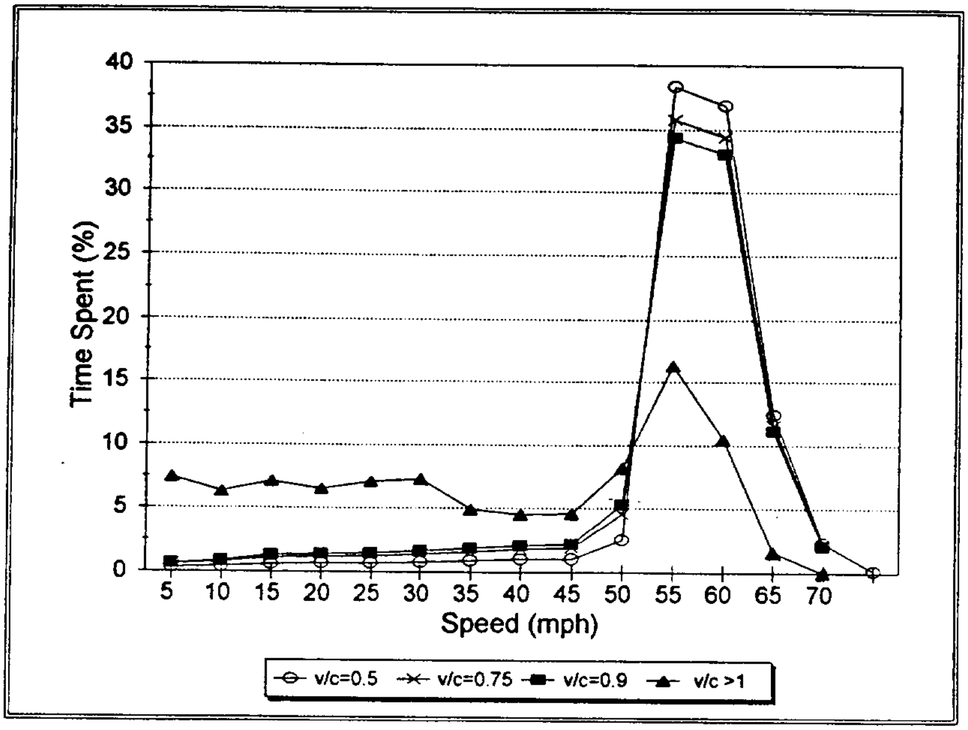
The speed distributions follow the same pattern for a wide range of traffic conditions. About 70 percent of the time was spent traveling at free flow speeds (55 to 60 mph.), with 15 percent of the time traveling at speeds of 65 mph or higher. Only 10 percent of the time was spent traveling at speeds less than 40 mph. The situation changes quite drastically for traffic volumes at or over capacity. Approximately 42 percent of the time is spent traveling at speeds of 30 mph or less with 7 percent of time in idle mode. The amount of time spent at desired free flow speeds drops to 25 percent.

Regarding the distribution of accelerations, the percent of time spent in acceleration rates of ± 2 mph or higher was only about 5 percent for undersaturated conditions, but increases to 13 percent for oversaturated conditions. The percent of cruising time drops by 20 percent for v/c greater than 1. Most of the time was spent in acceleration/deceleration of $\pm$ 1 mph under all flow levels.

The speed and acceleration distributions for weaving areas are shown in Figure 4.10. As was discussed earlier there is a wider range of times spent at different speeds compared to the basic freeway segments except for the low flow conditions. Under congested conditions, there is a uniform distribution of time spent in speeds between 5 to 50 mph with marginal proportions at higher speeds. Also, as shown in the Table 4.5 there is a significant increase in the time spent idling compared to the basic freeway segments. Note that the speed distribution shown for v/c of 0.9 is very similar to the speed distribution for v/c greater than 1 for basic freeway sections (Figure 4.9) Similar results were obtained throughout the simulation. This indicates that the time spent per driving mode for the weaving sections would be the equivalent distribution of basic freeway sections with reduced capacity.

The distribution of accelerations is similar to the one obtained for the basic freeway sections except the wider spread of values for the time spent in the cruise mode, and the greater proportion of accelerations of ± 2 mph or higher.

FIGURE 4.9 PREDICTED SPEED/ACCELERATION DISTRIBUTIONS FOR BASIC FREEWAY SEGMENTS



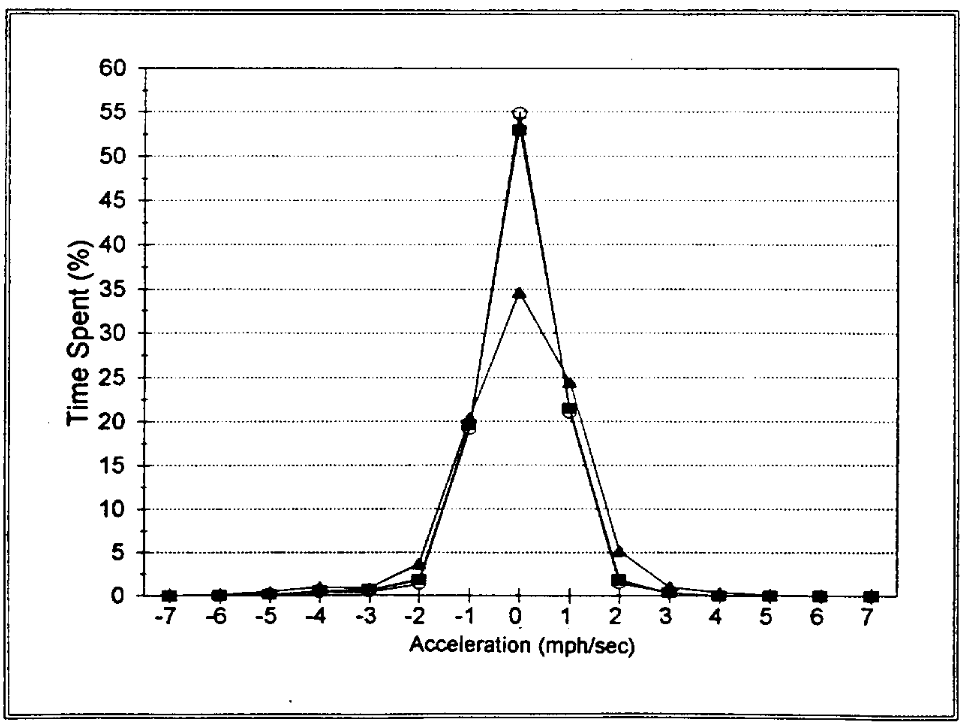
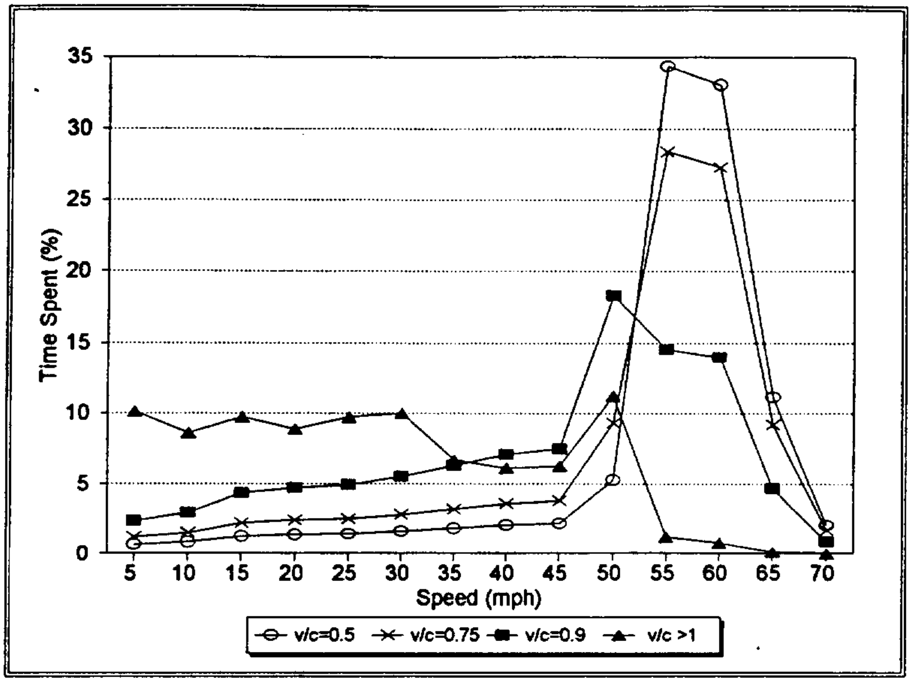
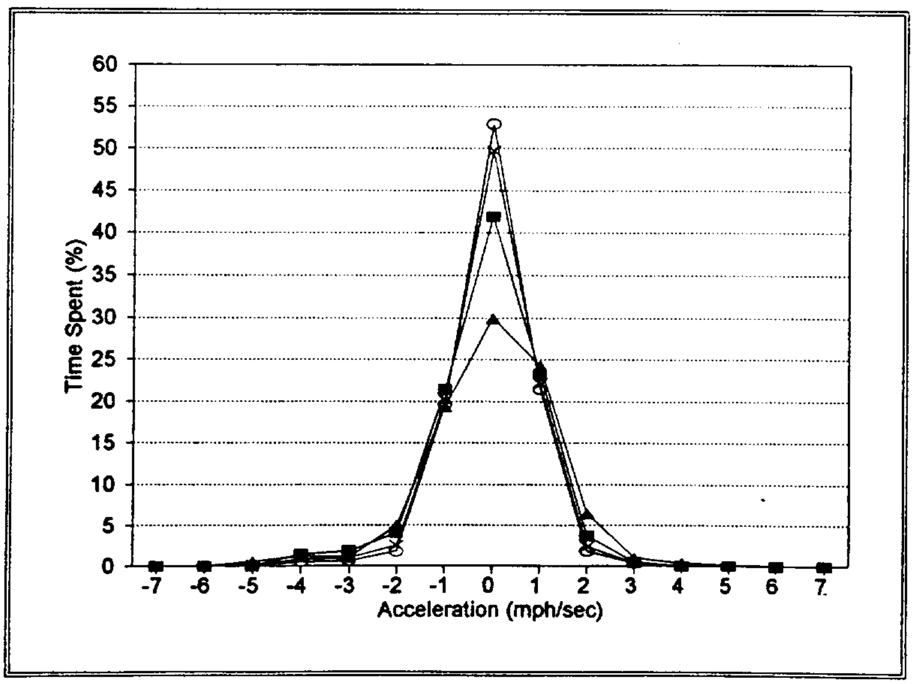


FIGURE 4.10 PREDICTED SPEED/ACCELERATION DISTRIBUTIONS FOR WEAVING AREAS



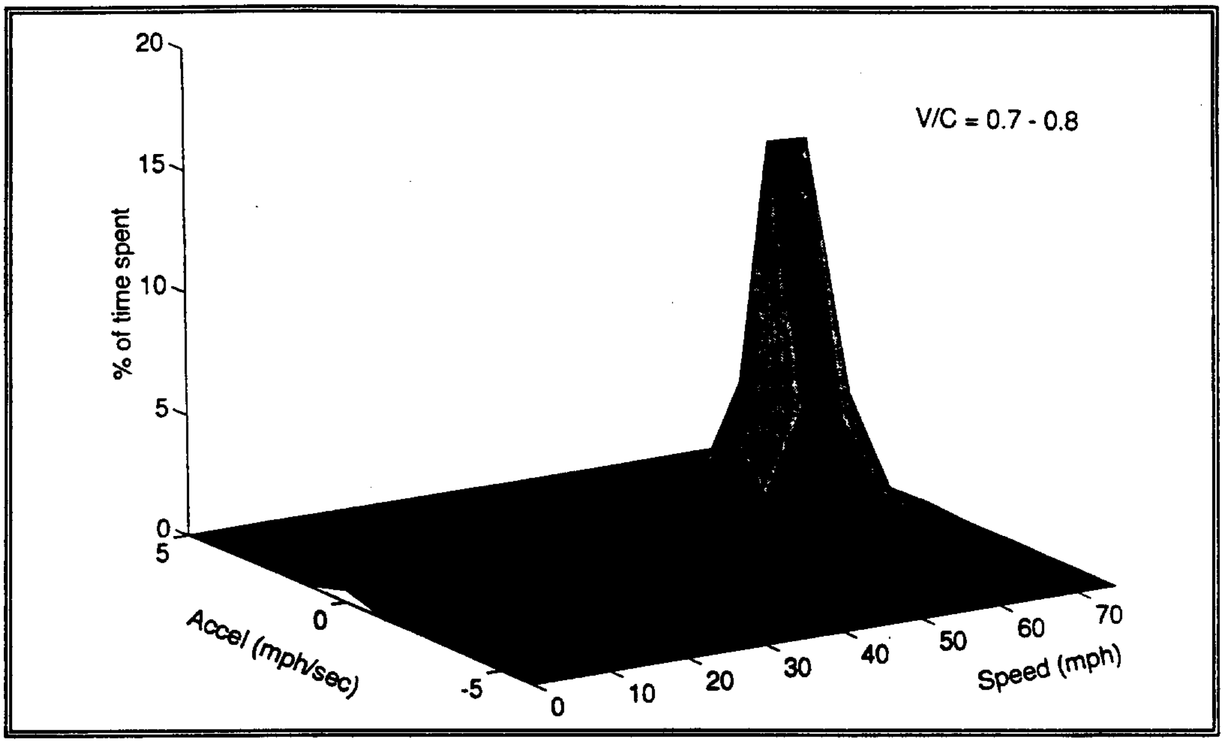


The availability of the data from the floating car runs on the I-880 freeway (30) provided us with the opportunity to determine speed-acceleration distributions based on field measurements and compare them with the simulation results. The test vehicles were equipped with a transmission speedometer transducer, a rate of turn indicator, a magnetic compass, a Geographic Positioning System (GPS), and a laptop computer. The in-vehicle data collection equipment stores information on incremental distance, magnetic direction, rate of turn, GPS data (longitude, latitude) and any codes entered by the drivers to (e.g., incidents.) Also, each time a test vehicle crosses the loop detectors at the boundary of each direction on the freeway, an event code along with the time is registered in the computer. This permits synchronization with the data from the loop detectors, since all the clocks in the vehicles and detector stations are synchronized with the California Highway Patrol's Computer Assistance and Dispatch (CAD) system. The instrumentation was calibrated to translate odometer readings into distance traveled by driving over exact distances on a test track.

The vehicles were driven over the test section at 5 minute headways for both the am and pm peak periods. They were entering and exiting outside the limits of the study area, and the drivers were instructed to drive on the lane next to the median lane and avoid unnecessary lane changing maneuvers. At the end of each data collection period, the data were downloaded on diskettes for further processing. The data processing and analysis software checks the raw data for accuracy, plots the vehicle trajectories and calculates travel times. The vehicle trajectories of the instrumented vehicles were extracted from the I-880 University of California's computerized database. A total of 213 floating car runs were processed along with traffic volume information from the loop detectors at the time of each run. The statistics of the time spent in each driving mode was determined for all the runs, and separately for groups of runs based on the volume/capacity ratio.

Figures 4.11 and 4.12 show three dimensional plots of the time spent, speed and acceleration for both undersaturated (v/c in the range 0.7 to 0.9) and oversaturated traffic conditions. Most of the vehicles travel close to free flow speeds almost up to capacity, with small time durations in acceleration and deceleration modes. At oversaturated conditions, the amount of cruising time is significantly reduced and actually there is a significant amount of time spent in slowdowns and stop and go traffic conditions. These results are very close to the simulation results for basic freeway segments shown in Figure 4.9.

FIGURE 4.11 I-880: MEASURED SPEED AND ACCELERATION DISTRIBUTIONS FOR UNDERSATURATED CONDITIONS



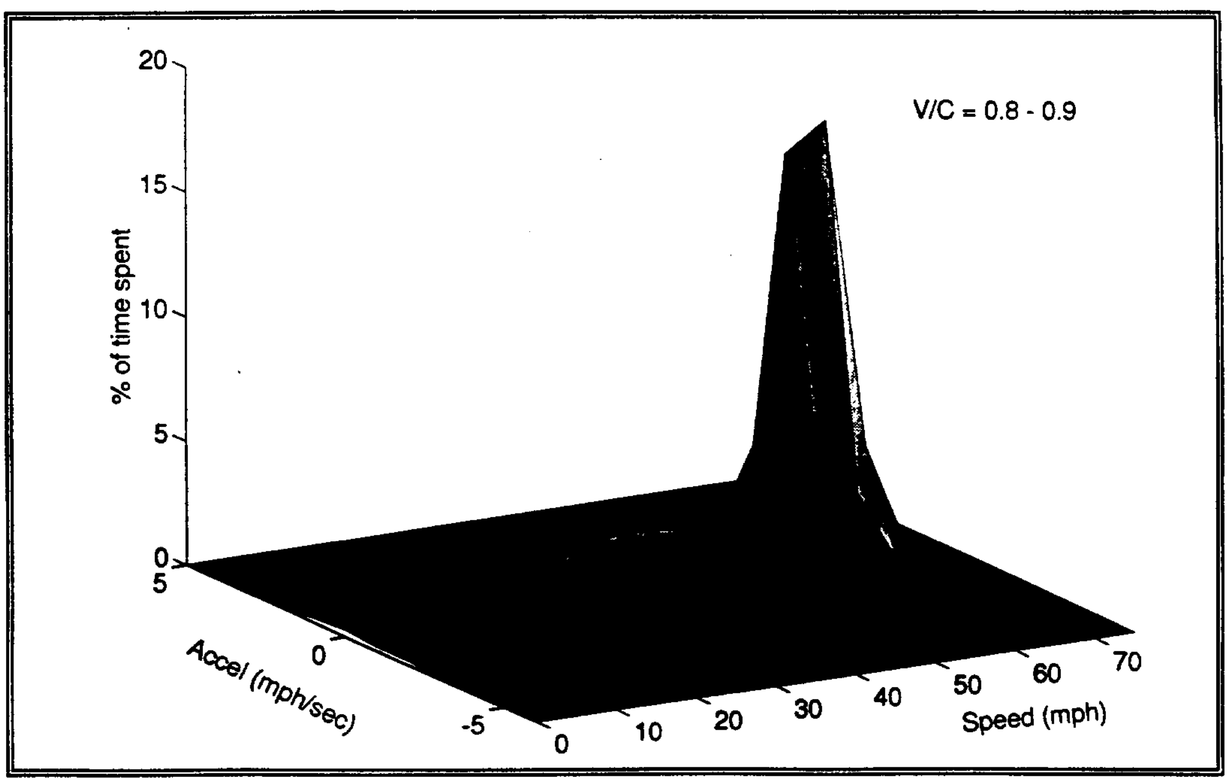
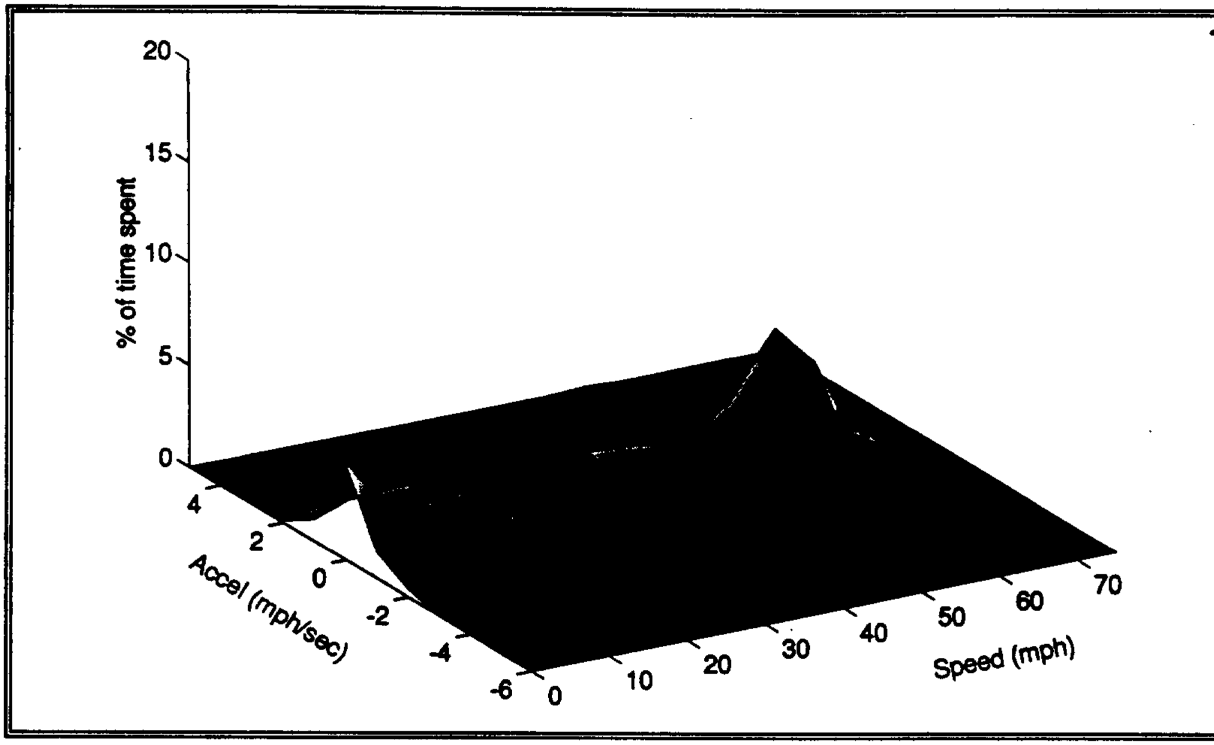
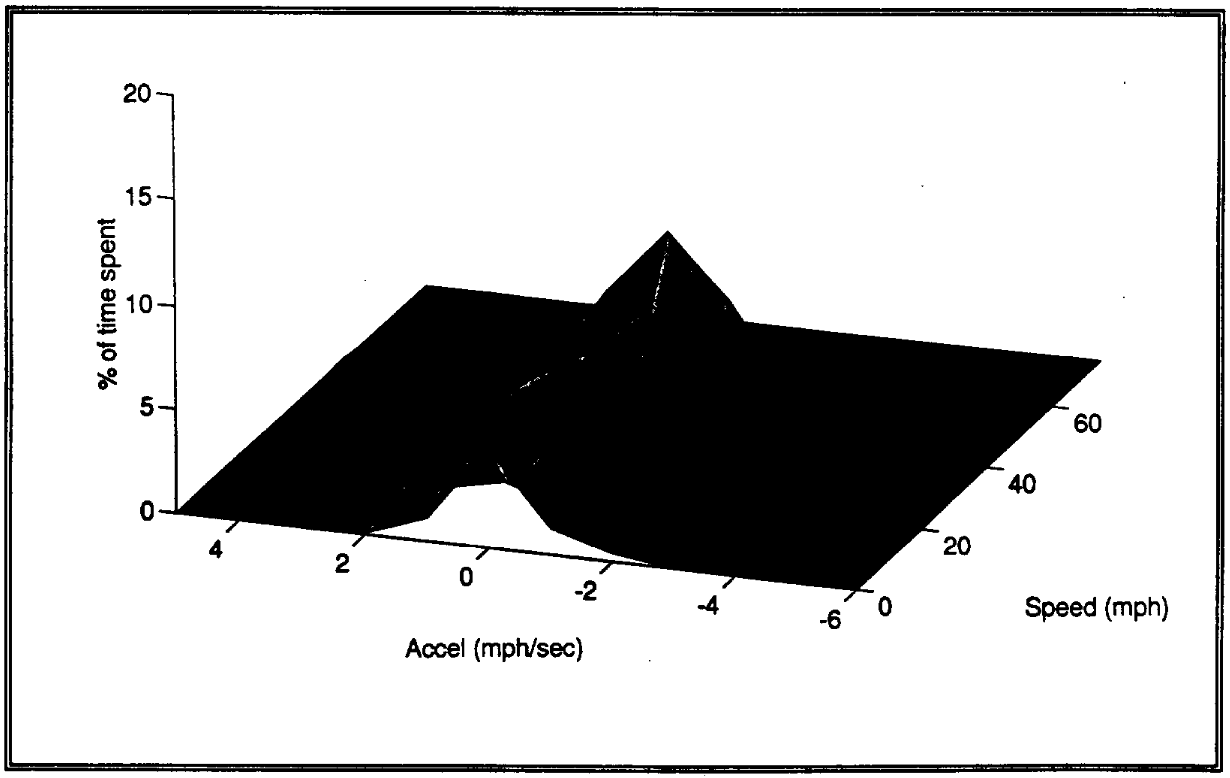


FIGURE 4.12 I-880: MEASURED SPEED AND ACCELERATION DISTRIBUTIONS FOR OVERSATURATED CONDITIONS



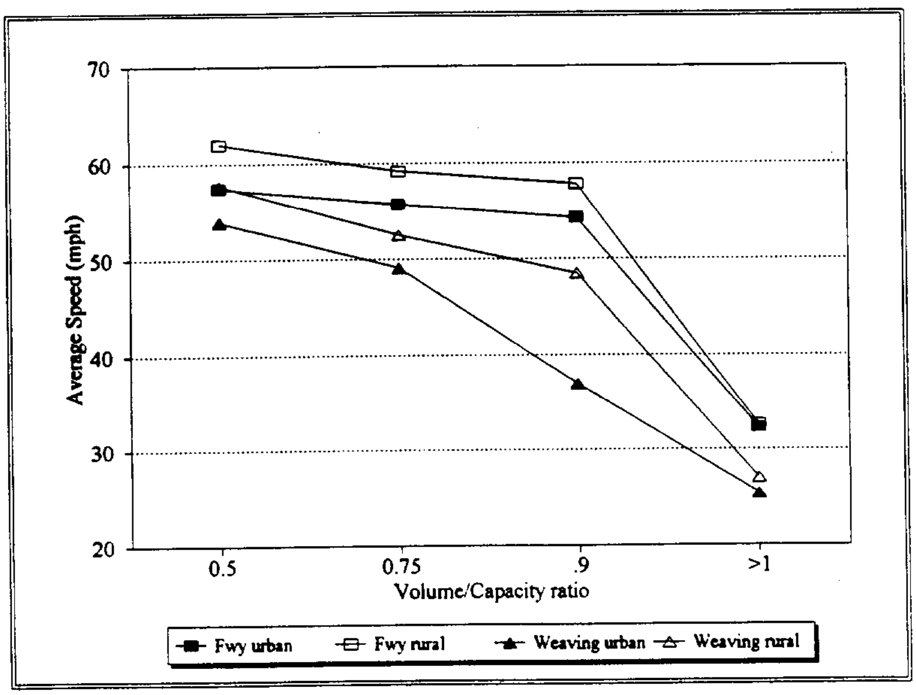


The results described above were obtained based on simulations and field data from freeway sites that represent urban conditions. Additional simulation experiments were performed to obtain vehicle activity from freeways typical of suburban/rural operating environments. This was accomplished by changing the basic design and operational characteristics, such of number of freeway lanes, free-flow speeds (in the range 65 to 70 mph), and longer weaving sections (from 2000 to 3500 ft). For each design scenario, multiple INTRAS runs were then made to simulate traffic conditions ranging from free to congested flow levels. Figure 4.13 shows the average speeds for basic freeway and weaving sections as a function of the v/c and the design characteristics.

The analysis of the results showed that for basic freeway segments, the times spent in each driving mode were similar to those found for the urban situations. The average speeds were higher by about 5 mph under free flow conditions, as expected because of the higher design standards. It should be noted that these results are representative of typical freeway sections and do not cover all the possible cases (e.g., narrow lanes, unusual grades and curvature, or other characteristics not commonly coded for planning and operations models.)

The effects of design characteristics are greater for the weaving sections. Vehicle activity tends to approximate the patterns obtained for the basic freeway segments for v/c ratios up to 0.9. This is especially true for long sections exceeding 3000 ft, indicating that traffic operations are outside of the realm of weaving. Note that the 1985 Highway Capacity Manual suggests a length of 2500 ft. as the area of weaving influence. For at, or over, capacity the times spent in each mode was basically the same as those for the urban sections. Again, these findings are based on simulations of typical conditions, and not on an exhaustive treatment of all the possible combinations of weaving configurations, design features and traffic distributions.

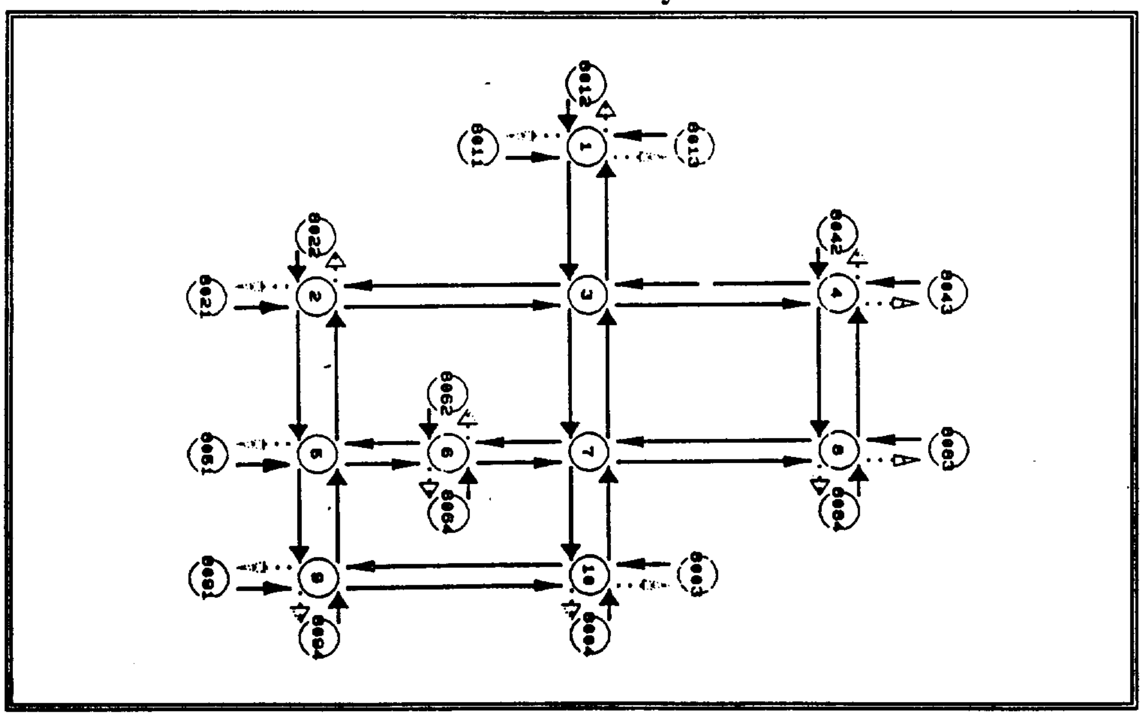
FIGURE 4.13 EFFECT OF DESIGN CHARACTERISTICS ON FREEWAY SPEEDS



4.3.2 The TRAF-NETSIM Model

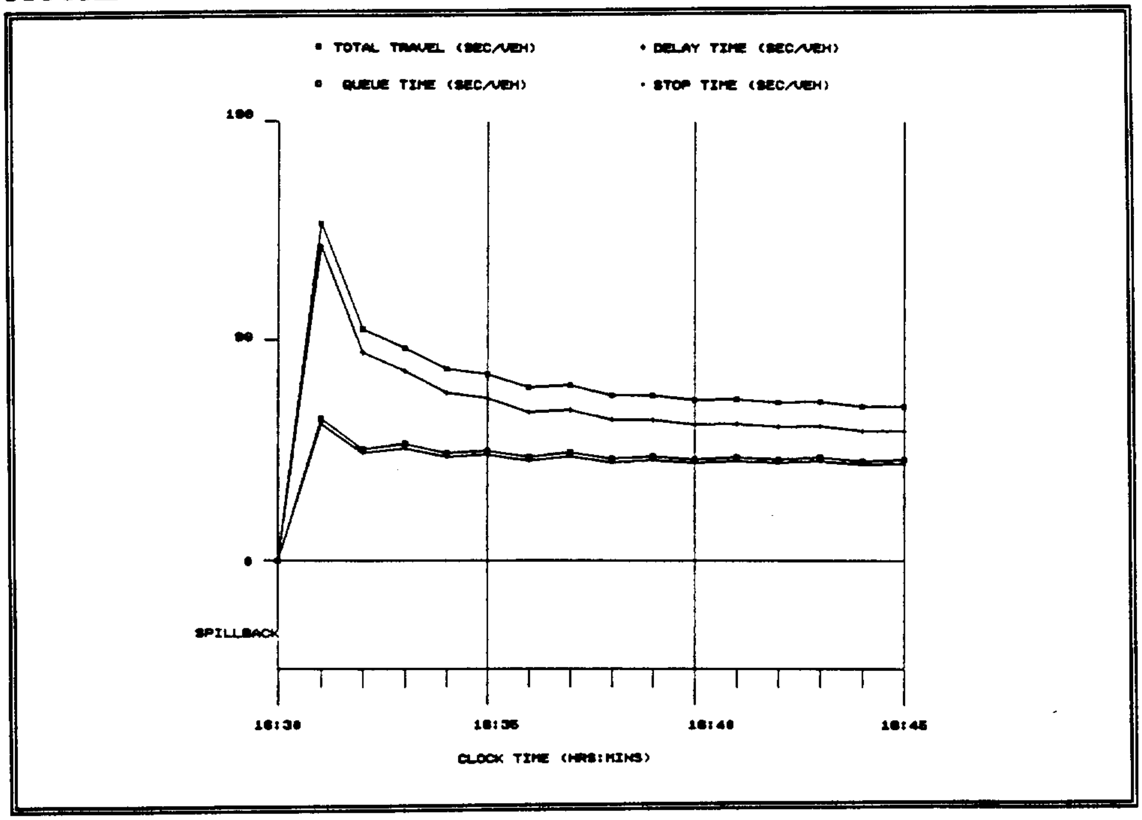
TRAF-NETSIM also requires the coding of the street network into links and nodes, with nodes representing intersections, and links one-way traffic streams. Figure 4.14 shows the network coding for the Berkeley CBD test site. Vehicles enter and leave the system via entry and exit nodes (#8xxx), and no output statistics are accumulated for the entry and exit links. Midblock changes along a link can be handled through dummy nodes. The input data for the basic application of the model are shown in Table 3.1, but additional inputs are required for simulating other conditions in a network, e.g., transit movements, parking activity, street blockages. The user can also override the values of certain embedded parameters and factors based on local conditions (e.g., emission rates). The model predicts travel time, delay, queue, stop time and stops at the signals, fuel consumption, and air pollutant emissions for each traffic movement, each link, and for the total network. Statistics are computed separately for autos and busses. A procedure developed by the study team permits the automatic post-processing of the voluminous NETSIM output using standard spreadsheet programs (LOTUS/QUATTRO)(34). The model also prints "snapshots" of the network, i.e., intermediate outputs on a second-by-second basis with the vehicle content, queue lengths and signal indication for each link.

FIGURE 4.14 TRAF-NETSIM CODING: Berkeley CBD



The selected networks were coded into the model. Several of the test sites have been already coded for the old NETSIM model and had to be converted and updated for the latest version of TRAF-NETSIM. Because small coding errors that could produce misleading results are very difficult to find, extreme care was exercised and considerable time and effort was spent to verify the input coding and to ensure that the considerable time and effort was spent to verify the input coding and to ensure that the model works as intended. Numerous runs were performed and the model outputs were thoroughly reviewed to identify any questionable data. The graphical and animation capabilities of the TRAF-NETSIM package were extensively used to review the input coding and the model results. Figure 4.15 shows an example of the graphical outputs for a network link that were used to verify the accuracy and the stability of the results throughout the simulation. The model predictions were also compared with information available on the performance measures of the test networks and adjustments were made as appropriate.

FIGURE 4.15 TYPICAL TRAF-NETSIM LINK GRAPHICAL OUTPUTS



The following modeling activities also were performed as part of the NETSIM application for the requirements of this study:

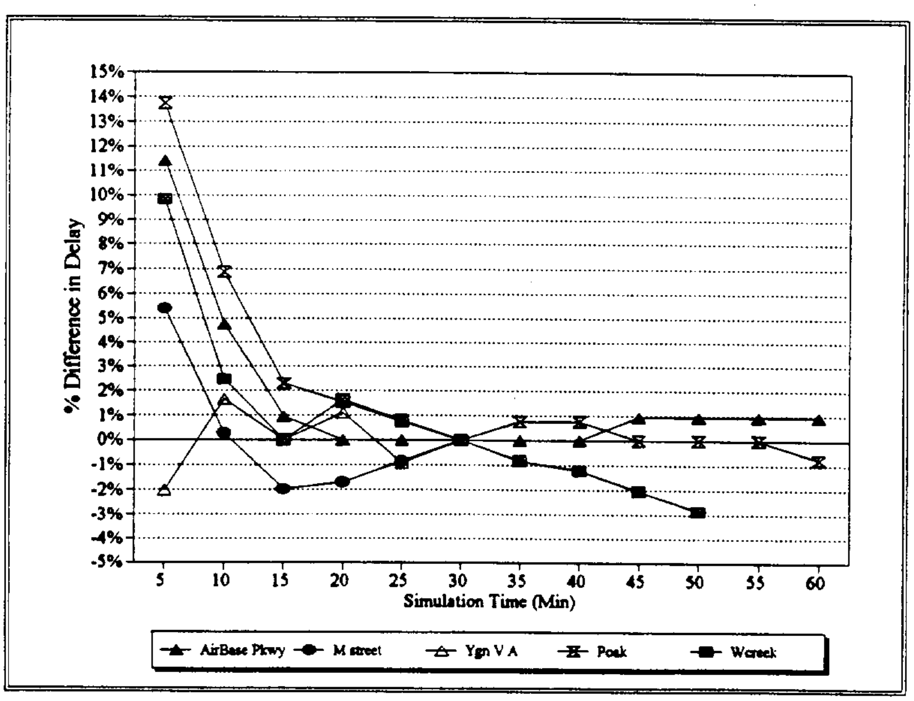
> Because TRAF-NETSIM cannot optimize the signal settings, and the quality of signal control is an important parameter in surface street operations, the networks were also coded for the widely used TRANSYT-7F simulation and optimization model. The TRANSYT model then determined for each network the best signal settings (cycle length, green times, and offsets.) These settings were then input to the TRAF-NETSIM model to simulate traffic operations under favorable signalization conditions (e.g., good progression on arterials.) The baseline timings

were modified in subsequent computer runs to simulate conditions of poor progression and uncoordinated signal operation (no common cycle and offsets between signals).

Several variations of the basic NETSIM data sets were also created to model characteristics of link types that were not sufficiently represented in the selected data sets. For example, to obtain vehicle activity outputs for widely spaced suburban/rural expressways the link distance, geometrics and signal controls had to be modified from the base test site. NETSIM, however, cannot handle links longer than 4000 ft (0.75 mile), and special dummy nodes with 100 percent green time had to be coded.

The stochastic variability of the NETSIM results was also investigated through multiple computer runs with different random number seeds and simulation times on several test networks. Figure 4.16 shows the results from five test sites. The difference in delay shown in the percent difference between the predicted delays (min/mile) at each time interval and at 30 minutes of simulation time. These findings indicate that the variability in the model results is within 3 percent, and suggest that 30 minute long simulations with the default random number seed provide sufficient accuracy. The results are similar to the findings from other studies as was discussed in Section 3.1.3.

FIGURE 4.16 STOCHASTIC VARIABILITY OF NETSIM RESULTS



Next, a series of simulations were performed on each test site to obtain the time spent in each driving mode. The results were tabulated and analyzed separately for each link, each part of the network (e.g., arterials vs. cross-streets) and the total network. Analyses were then performed to determine differences and similarities in vehicle activity between the designated link types for a range of traffic conditions for both dissagregate and aggregate measures. This has been a complicated process given the test sites to be simulated and the variation in their characteristics. The results presented below describe the key findings to be used for developing the relationships.

Figure 4.17 shows the vehicle activity for all the eight arterial data sets. The results show that the largest variations are in the cruise and idle times. Times spend in deceleration and acceleration are similar in all the networks, except for the urban section of the Ygnacio Valley Rd. (Section A). This section is a closely spaced arterial operating close to at saturation with heavy conflicting movements. Therefore, there is a high amount of delay (and idle time) at the traffic signals with considerably lower times in the cruise and acceleration modes. The variation in cruise and idle time in the rest of the networks is due to their geometric characteristics, traffic patterns and signalization.

The speed and acceleration distributions for the links in Nicholasville Rd and Ygnacio Valley (Section B) are shown in Figure 4.18. These arterials are typical examples of suburban arterials with 40 mph free flow speeds, predominant arterial through traffic and favorable progression along the heavier traffic movements. They are have about the same average signal spacing. It can be seen that the times spent in each driving mode are very similar on both sites. The speed distribution is "flatter" on the Ygnacio Valley Rd due to smaller variation in the distance between intersections.

Figure 4.19 shows the vehicle activity data for the El Camino and Ygnacio Valley (Section A) arterials to illustrate the effects of congestion levels and traffic patterns. As Table 4.4 shows both of these arterials have similar characteristics in terms of signal spacing, free flow speeds and signalization conditions. However, as it was mentioned above, the traffic volumes are considerable heavier on Ygnacio Valley which explains the low proportion of times spend in cruise and at the desired speed.

Figure 4.20 shows the speed distributions (including the idle time) for the four selected grid networks. The results are plotted separately for the Core/CBD type networks (Berkeley CBD and Walnut Creek CBD) and the urban suburban networks (Post Oak and Silver Lake.) The speed distributions for the CBD type networks are very similar and show that a significant amount of time is consumed idling and at low travel speeds primarily because of the short intersection spacing and numerous vehicle pedestrian conflicts at traffic signals. Urban/suburban type networks have lower proportions of time spent idling and higher speeds. The difference in the distributions between Silver Lake and Post Oak are due to their different free flow speeds. The shape of the distributions is basically the same should be proportion of time spent normalized with the free flow speed.

The effects of signal spacing, signal control and free flow speeds on vehicle activity are illustrated in Figure 4.21 using the M Street and AirBase Parkway test sites. AirBase

Parkway is an expressway type facility with high design standards, high free flow speeds and signal control. M Street in contrast is a very closely spaced arterial. The time spent traveling at free flow speeds is about 60 percent compared to 30 percent for the M-Street. Regarding the cross-streets (collector streets approaching the arterial) their performance depends on the amount of green time they receive at the intersection with major arterials. It can be seen that the AirBase Parkway approach roadways have extremely high proportion of their time spent in idling and at low speeds, where in the M Street test site with about equal split of green times between the arterial and the cross streets the speed distributions of the two link types are very similar.

The major findings from the extensive analysis of the NETSIM results indicated that the link types selected for surface street networks capture most of the variability in traffic performance due to the differences in design, control and traffic characteristics among the different facilities.

FIGURE 4.17 PREDICTED VEHICLE ACTIVITY: ALL ARTERIAL SITES

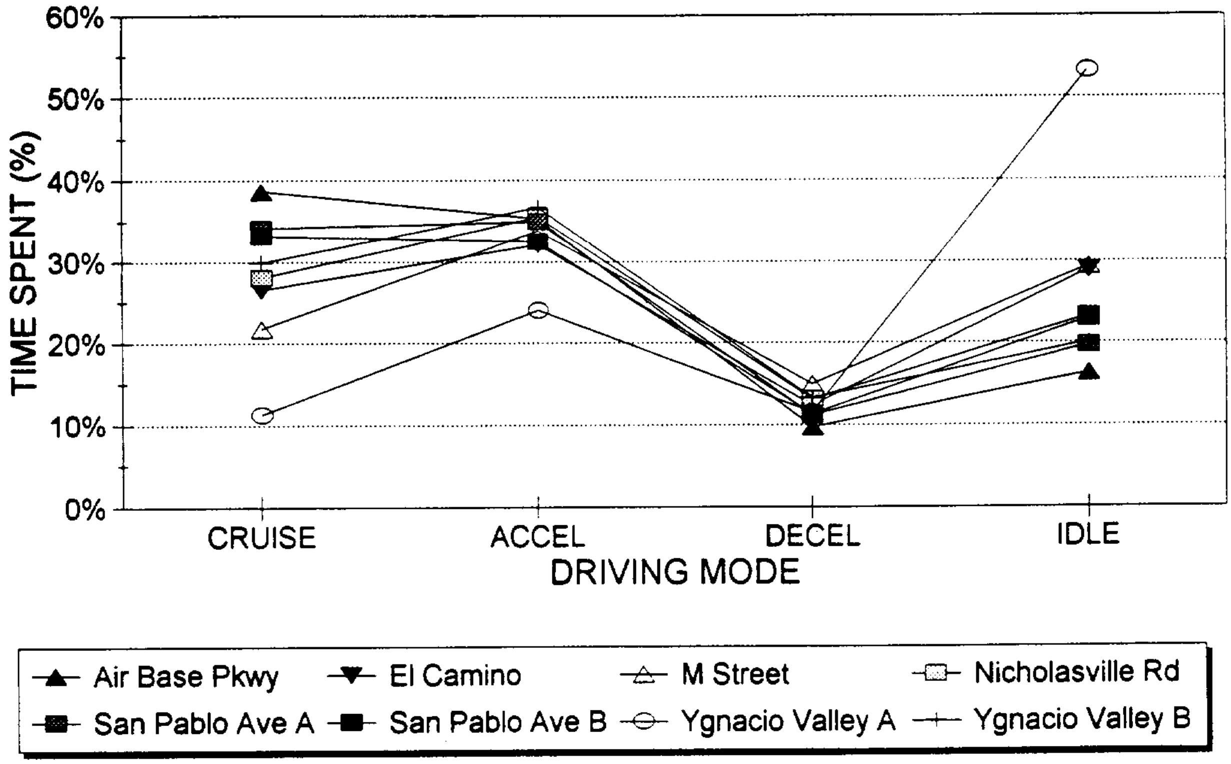
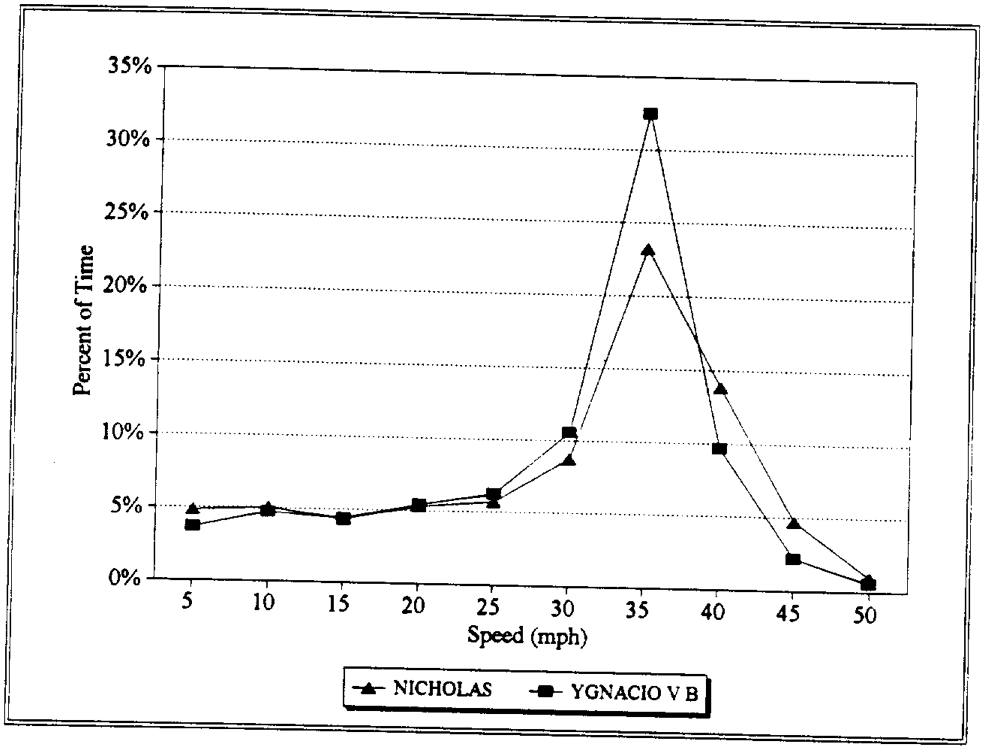


FIGURE 4.18 SPEED/ACCELERATION DISTRIBUTIONS FOR SUBURBAN ARTERIALS



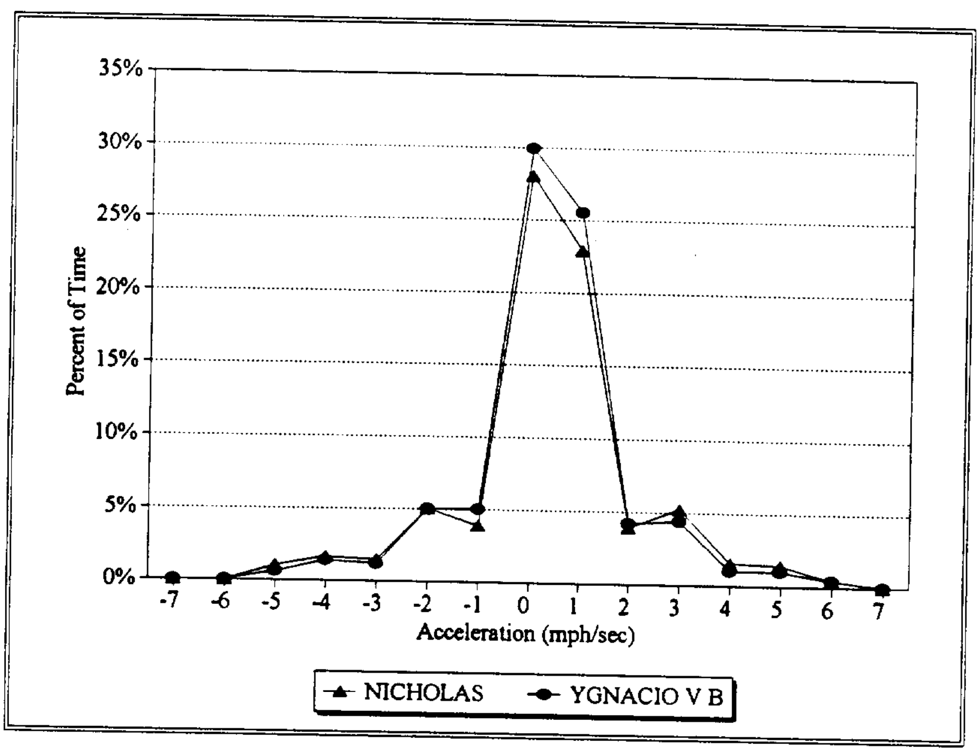
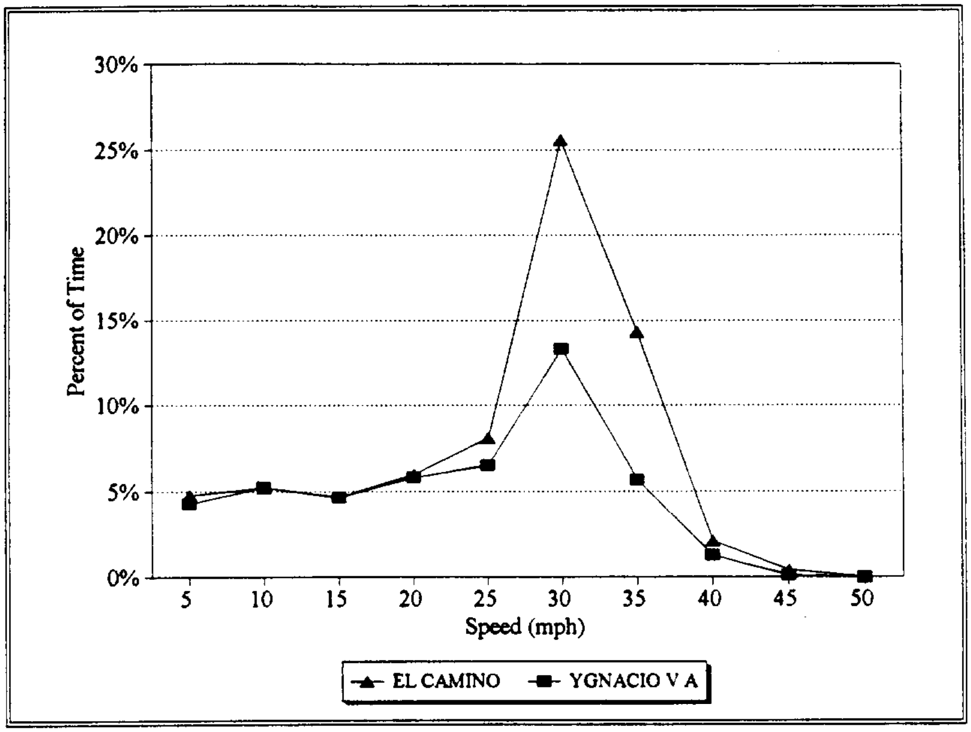


FIGURE 4.19 SPEED/ACCELERATION DISTRIBUTIONS FOR "DENSE" ARTERIALS



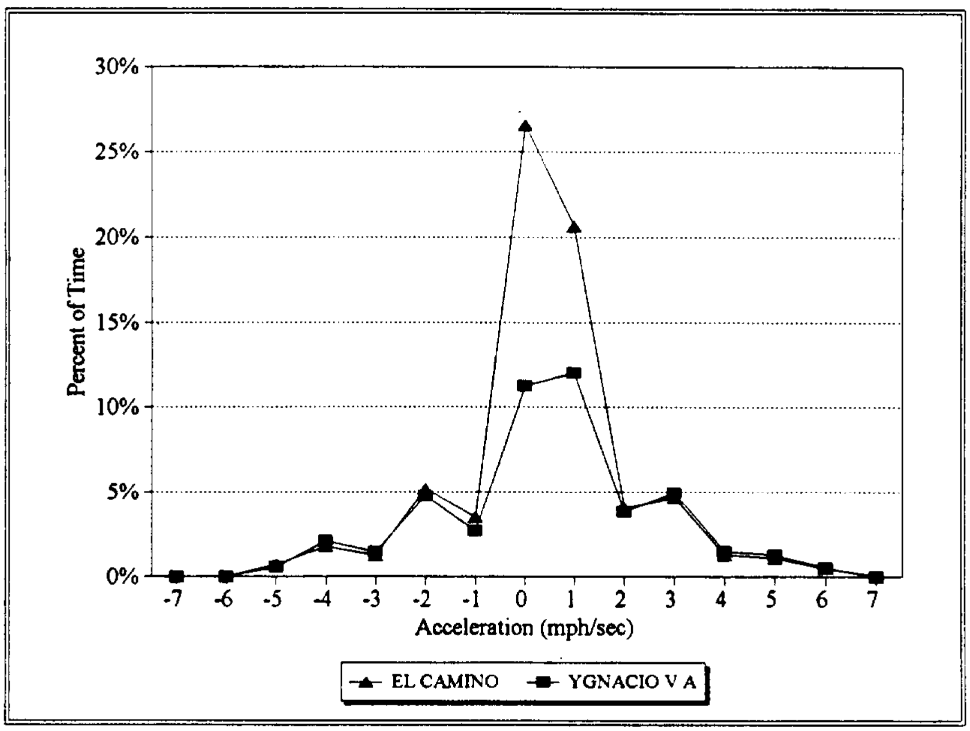
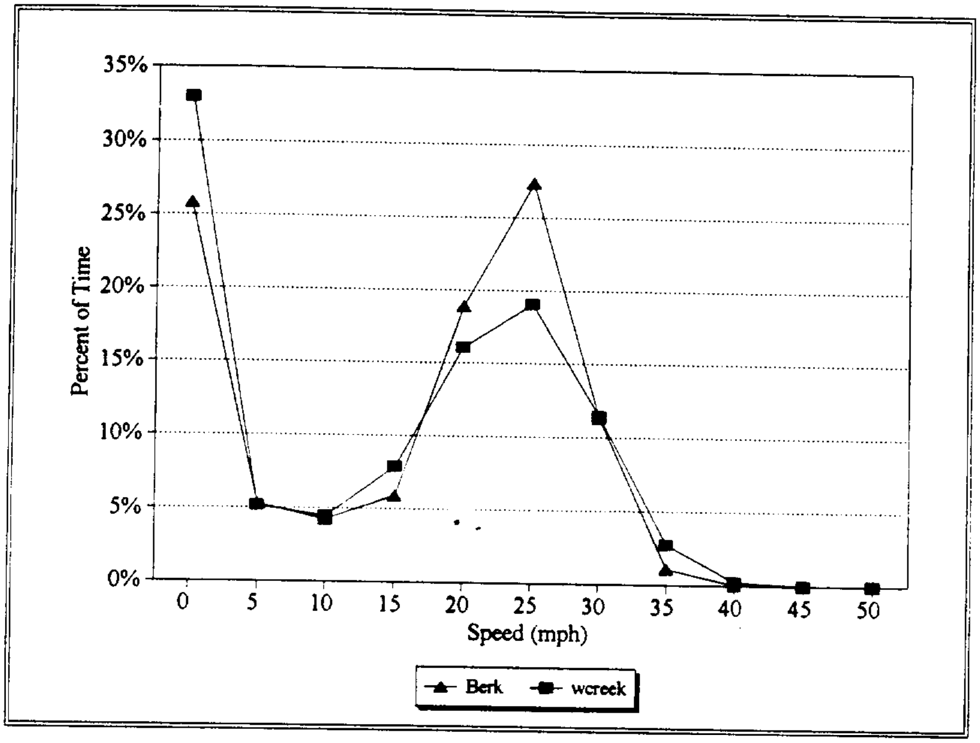


FIGURE 4.20 SPEED/ACCELERATION DISTRIBUTIONS FOR GRID NETWORKS



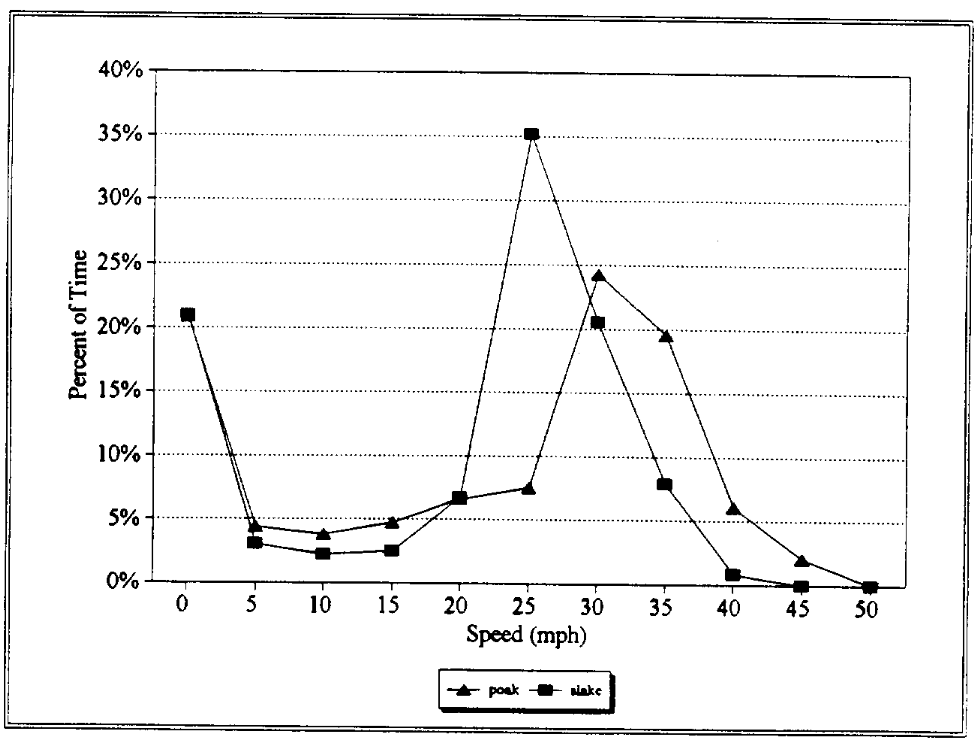
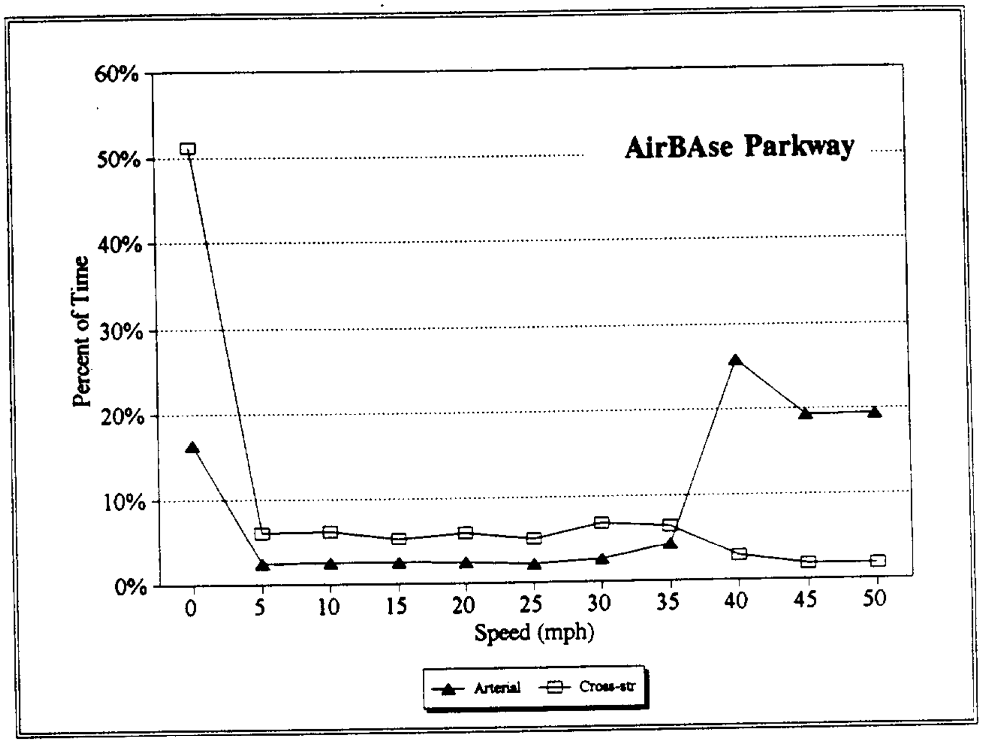
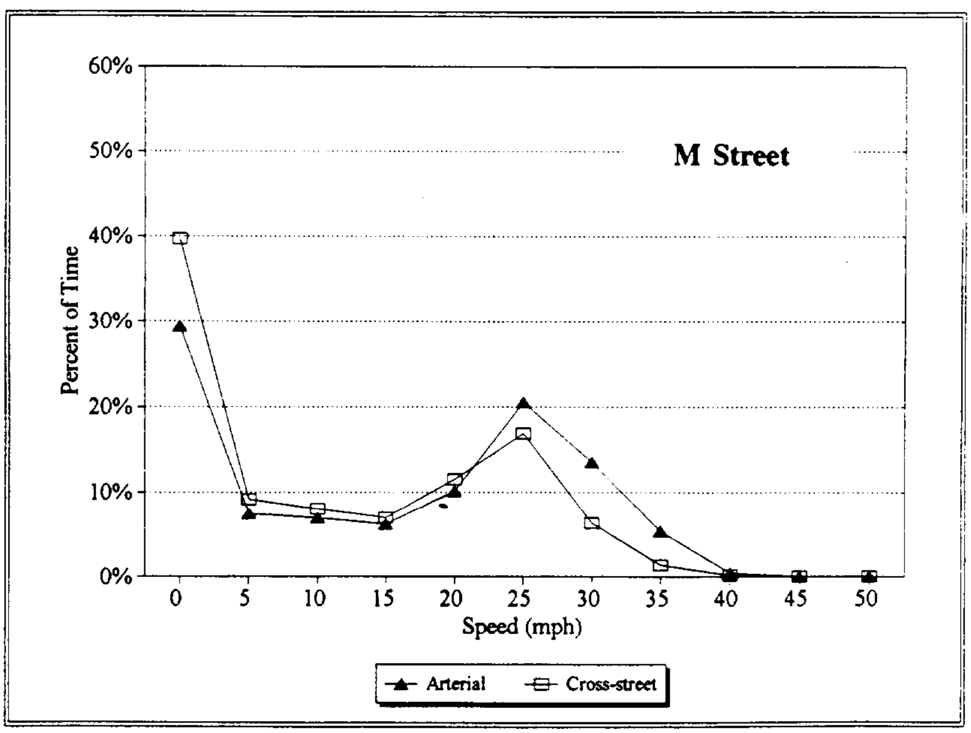


FIGURE 4.21 SPEED DISTRIBUTIONS FOR ARTERIALS AND COLLECTOR STREETS





4.4 Development of the Post-Processor to MINUTP Model

The predicted link vehicle activity data from the simulations on each test site were analyzed to determine the time-spent per driving mode for each of the proposed link types shown in Table 3.3. These estimates were further analyzed to determine significant differences in the time-spent estimates within a link type and across the link types. The analyses and comparisons on vehicles activity analyses were performed for links representing single segments (e.g., a street segment between two signalized intersections) and for links consisting of several road segments. This process produced a set of relationships defined by the link type, the v/c ratio, and the free-flow speed.

The predicted values of time-spent in idle mode in the vehicle activity relationships represent the time spent 'traveling' with zero speed (i.e., vehicles stopped at traffic signals,) and do not include any key on/off operations. Also, the relationships was developed assuming vehicles with average performance characteristics, and no specific relationships were developed separately for light, medium or heavy duty vehicles in the traffic stream. Information on vehicle composition is not typically coded in the four-step planning models.

The next step was to translate the proposed link types in the study (Table 3.3) into equivalent link types based on the facility/area type designations (Table 3.4) to avoid recoding all the links in the MTC network in order to apply the integrated model. The conversion process considered the approach and assumption made for designating the MTC link types (29), the characteristics represented into the proposed link types in this study, and the findings from the simulation experiments. A new variable is computed (link ID) which is stored along with the rest of the information on the link characteristics that are used to calculate vehicle activity.

The greatest difficulty in the link type conversion was to account for the effects of weaving on freeways and signal timing on arterials, especially for links consisting of several signalized intersections. The final selection of the "equivalent" link types was based on the assumptions by MTC on estimating capacity for those facilities (green/cycle time ratios, and the findings from the simulation results on vehicle activity for a combination of links with various degrees of progression quality. The process for determining equivalent link types for the MTC network is described in detail in the post-processor's User's Guide (Appendix B.)

The post-processor to the MINUTP model consists of two main modules. The AIRQ.SET command file for link data processing, and a FORTRAN program (AIRQ) to estimate vehicle activity. The basic computational procedures in each step are described in the following sections. A User's Guide with detailed documentation on the software and its application is included in Appendix B.

4.4.1 Link Data Processing

The first module (**AIRQ.SET**) was written as a MINUTP command file using the commands of the NETMRG data manipulation routine to process the output from the MINUTP model run. This module first calculates the link capacity, vehicle miles of travel (VMT), and vehicle-hours of travel (VHT) as follows:

Capacity=(Capacity/lane)(# lanes)*
*VMT=Volume*Distance (Veh-mi)*100*
*VHT=Volume*Congested Time (Veh-min)*100*

The program then produces an ASCII text file with the following link data fields in each record:

Anode, Bnode, Distance, Free Speed, Capacity, Link Type, Volume, Avg Speed, v/c,VMT, VHT

However, the 1120 MTC zone network selected for the model demonstration in this study does not include the free-flow speed and the link type as variable names. Therefore, a special version of the command file (**AIRQMTC.SET**) was created to code this information according to the following steps:

(1) Code the free flow speed for each link based on the values in the facility/area type table. For example, the free-flow speed (FFS) for the freeway-to-freeway links is coded as follows:

@ FT=1,AT=0-1 FFS=40
@ FT=1,AT=2-3 FFS=45
@ FT=1,AT=4-5 FFS=50

Any future revisions to the free-flow speeds could be easily changed in this command file by specifying the appropriate value for the appropriate FT/AT designation. Note that the earlier MTC 700 zone model had the free-flow speed coded (SPDC), so a variation of the set file (**AIRQMTC7.SET**) was created by commenting-out all such statements.

(2) Determine the link types based on the facility/area type designations as described in the previous section. Similar to the procedure for coding the free flow speeds, the AIRQMTC.SET command routine computes a new variable link ID which is

stored along with the rest of the information on the link characteristics. The determination of the link ID is illustrated below for the arterial links in the 1120 zone MTC network:

@ FT=7,AT=0-1 ID=9	*Core/CBD arterial links*
@ FT=7,AT=2-3 ID=10	*UBD/Urban arterial links*
@ FT=7,AT=4 ID=11	*Suburban arterial links*
@ FT=7,AT=5 ID=4	*Rural arterial links*

The data file produced by the AIRQMTC.SET file includes the following fields in each record:

Anode, Bnode, Distance, Free Speed, Capacity, Fac type, Area type, Volume, Avg Speed, v/c, Link ID, VMT, VHT

The AIRQMTC.SET routine processes by default all the network links with traffic volumes except the centroid connectors. Users may specify other criteria for selecting the links to be processed through the IF, USE, SKIP statements of the NETMRG routine in the AIRQMTC.SET file. This provides flexibility in selecting specific areas or highway facilities for processing (e.g., a specific county, freeways only) to calculate the vehicle activity with the AIRQ program.

The listing if the AIRQMTC.SET command file is included in APPENDIX D.

4.4.2 Estimation of Vehicle Activity

AIRQ is a FORTRAN program to calculate the time-spent in each driving mode using the link data file created by the AIRQMTC.SET module based on the link type/vehicle activity relationships developed from the analysis of the simulation results. These relationships are stored in tabular form in a file (AIRQTBL.TBL) and are read by the AIRQ program. Each cell of those tables represents the percent of total travel time spent in a particular speed-acceleration category. The following steps are performed by the AIRQ program:

(1) Use the link type (ID) and v/c ratio (VC) values to determine the appropriate table to use stored in the AIRQTBL.TBL file. If the link free-flow speed (FFS) value is different than the FFS used in the selected speed/acceleration distribution table, then the values in the table are adjusted to provide the correct proportion of travel time for the link specific free-flow speed. This process is applied to improve the accuracy of estimates for links with the same link ID but different free-flow speeds (e.g., core vs. CBD arterial facilities in the MTC network.)

(2) Calculate the time-spent for each link based on the VHT and the speed/acceleration distribution table determined from Step (1). Produce tables of time-spent by speed/acceleration category for speeds from 5 to 65 mph (at 5 mph intervals) and accelerations from -7 to +7 mph/sec (at 1 mph/sec intervals) and the idle mode.

(3) Accumulate statistics for each link, area type/facility type and the total network. Print out results.

The AIRQ program is written in Microsoft FORTRAN 5.1 and is operational on PC based 386/486 microcomputers. The program can be executed in interactive or offline (batch) mode. The interactive version of the program is menu driven, and allows the user to specify the input/output files, run the program and view the results. Figure 4.22 shows the main menu for the AIRQ program. The batch mode allows to perform multiple runs and run the program from within the AIRQMTC.SET command file following the processing of the MINUTP output. The program running options are explained in detail in the User's Guide (Appendix B.)

FIGURE 4.22 AIRQ PROGRAM: INTERACTIVE VERSION MAIN MENU

```
*****************************************************
*              A-I-R-Q     POST-PROCESSOR           *
*    ESTIMATION OF TIME-SPENT PER DRIVING MODE      *
*  FROM THE OUTPUT OF "FOUR-STEP" REGIONAL MODELS   *
*---------------------------------------------------*
*                                                   *
*       1. Run the Program                          *
*       2. View Network Statistics                  *
*       3. View Link Summary Performance            *
*       4. View Link Specific Vehicle-Activity      *
*       5. Exit                                     *
*                                                   *
*****************************************************



  Enter Menu Choice
```

The program produces several types of outputs on vehicle activity for each link, facility type/area type and the total network. The output options in the AIRQ program described below have been designed to provide vehicle activity estimates for any level of network detail, and to be used for emissions estimation for any type of emission factors available. Also, the user can select the amount of output generated in each program run.

A. Network Statistics:

- Vehicle-activity (veh-hr) by speed-acceleration category for the entire network and for each facility type (Figure 4.23). This output can be used for direct estimation of the emissions in the network using modal emission factors.

- Summary statistics for the network including VMT, VHT, Vehicle-hours of Delay (VHD) and average travel speed (Figure 4.23). The VMT, VHT and speed values are obtained from the MINUTP model estimates. The delay is calculated by the AIRQ program as the difference in time between traveling at the specified free-flow speed and the average travel speed. The output can be used for estimating emissions based on the speed-based emission factors and VMT.

- Total time spent in cruise, acceleration, deceleration and idle mode for the entire network by facility type and area type (Figure 4.24). This allows estimation of emissions based on aggregate emission rates for each driving mode.

B. Link Performance Summary

- This output (Figure 4.25) provides information on the basic link characteristics, traffic performance (speed, v/c, VMT, VHT, VHD), and the total time spent in each driving mode (Figure 4.25). This information could be used to estimate link specific emissions based on simplified emission factors.

C. Link Specific Vehicle Activity

- Vehicle-activity (veh-min) for each link by speed-acceleration category (Figure 4.26). The output also includes the link identification (Anode, Bnode), facility and area type and the total veh-hr of travel. The output can be used for estimating link emissions based on modal emission factors.

  This output option generates large files especially for big networks. For example, about 14 MB of hard disk storage would be needed for the 22,000 links processed from the MTC 1120 zone network. The user, however, can suppress this output by coding the appropriate value for the output level flag.

The program also prints out selected outputs in unlabelled ASCII format (TABLEx.PRN) to facilitate further analysis. For example, the unlabelled file with network estimates (TABLE1.PRN) can be used directly in a program with modal emissions factors to calculate emissions without re-entering the vehicle activity data.

FIGURE 4.23 NETWORK VEHICLE ACTIVITY OUTPUT FROM THE AIRQ PROGRAM

VEHICLE ACTIVITY FOR THE TOTAL NETWORK
TIME-SPENT (Veh-hr) BY SPEED(mph) and ACCELERATION(mph/sec)

"MPH"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	TOTAL
0	.0	.0	.0	.0	.0	.0	.0	3292.3	.0	.0	.0	.0	.0	.0	.0	3292.3
5	.0	.0	48.2	49.6	49.6	479.3	1255.3	1532.7	1351.8	328.5	97.8	48.2	.0	.0	.0	5241.0
10	.0	.0	48.2	49.6	110.0	364.8	815.2	1217.5	973.5	304.4	48.2	48.2	.0	.0	.0	3979.6
15	.0	.0	48.2	110.0	110.0	364.8	973.5	1436.1	1131.7	461.2	108.6	48.2	.0	.0	.0	4792.4
20	.0	.0	.0	110.0	110.0	316.5	1035.3	1354.6	1181.4	413.0	108.6	.0	.0	.0	.0	4629.4
25	.0	.0	.0	108.6	110.0	364.8	1087.8	1463.3	1389.4	413.0	48.2	.0	.0	.0	.0	4985.0
30	.0	.0	48.2	110.0	110.0	316.5	1196.4	1573.4	1451.1	459.7	.0	.0	.0	.0	.0	5265.4
35	.0	.0	.0	110.0	158.2	220.1	937.7	1301.6	1335.7	316.5	48.2	.0	.0	.0	.0	4428.0
40	.0	.0	1.4	49.6	61.7	221.4	1167.4	1473.4	1456.8	317.9	.0	.0	.0	.0	.0	4749.5
45	.0	.0	.0	108.6	60.4	220.1	1157.5	1821.7	1372.5	161.0	1.4	.0	.0	.0	.0	4903.2
50	.0	.0	.0	60.4	60.4	170.4	2236.0	4688.3	2292.7	170.4	1.4	.0	48.2	.0	.0	9728.0
55	.0	48.2	108.6	108.6	60.4	229.4	5564.5	13195.8	5419.8	277.6	.0	.0	.0	.0	.0	25013.0
60	.0	.0	.0	.0	.0	120.8	4032.5	12170.8	4744.6	277.6	156.9	48.2	.0	.0	.0	21551.4
65	.0	.0	.0	.0	.0	60.4	1195.7	4287.1	1654.5	108.6	108.6	.0	.0	.0	.0	7414.9
TOTAL	.0	48.2	302.9	974.9	1000.6	3449.2	22654.8	50808.4	25755.5	4009.6	727.9	192.9	48.2	.0	.0	109973.1

NETWORK SUMMARY STATISTICS

TOTAL DISTANCE TRAVELED (VMT):	4918830.0
TOTAL TRAVEL TIME (VHT):	109973.1
TOTAL DELAY (VHD):	31145.3
AVERAGE NETWORK SPEED (MPH):	44.7

FIGURE 4.24 NETWORK SUMMARY BY VEHICLE TYPE AND FACILITY TYPE

1 SUMMARY STATISTICS FOR THE NETWORK

TOTAL TIME-SPENT IN CRUISE MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	61.31	.00	104.43	37.36	.00	486.63	.00	689.73
CBD	8.32	372.98	31.72	259.29	293.24	.00	1334.51	.00	2300.06
UBD	293.26	5162.74	1637.43	1076.36	636.96	.00	5083.31	.00	13890.05
URBAN	681.99	16253.20	1093.96	3618.56	1437.94	.00	9395.71	.00	32481.36
SUBURBAN	220.65	17654.44	985.65	3159.34	2511.77	.00	8527.00	.00	33058.86
RURAL	26.41	6780.73	288.56	2785.75	111.71	.00	3200.28	.00	13193.45
TOTAL	1230.64	46285.41	4037.32	11003.73	5028.98	.00	28027.43	.00	95613.52

TOTAL TIME-SPENT IN ACCELERATION MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	30.60	.00	77.66	22.88	.00	470.56	.00	601.70
CBD	3.94	246.74	48.63	328.74	246.13	.00	1350.80	.00	2224.98
UBD	170.68	3237.97	1622.97	1305.01	352.45	.00	5121.34	.00	11810.43
URBAN	421.03	11681.64	1018.70	5274.57	989.15	.00	9289.05	.00	28674.14
SUBURBAN	127.69	11118.34	840.48	3933.57	2066.75	.00	10284.88	.00	28371.72
RURAL	13.14	3682.32	247.54	3057.16	54.01	.00	2924.72	.00	9978.89
TOTAL	736.49	29997.62	3778.32	13976.70	3731.37	.00	29441.36	.00	81661.85

TOTAL TIME-SPENT IN DECELERATION MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	30.29	.00	34.42	20.57	.00	208.44	.00	293.72
CBD	3.87	227.12	20.34	150.76	209.70	.00	612.57	.00	1224.36
UBD	159.53	3018.16	553.69	602.41	328.33	.00	2054.28	.00	6716.41
URBAN	388.62	10550.13	335.31	2475.73	878.78	.00	3664.00	.00	18292.56
SUBURBAN	121.37	10355.52	255.55	1791.45	1776.27	.00	4169.42	.00	18469.58
RURAL	13.01	3562.96	68.02	1378.83	52.01	.00	939.04	.00	6013.88
TOTAL	686.40	27744.18	1232.92	6433.60	3265.67	.00	11647.74	.00	51010.50

TOTAL TIME-SPENT IN IDLE MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	.44	.00	17.74	2.09	.00	250.83	.00	271.10
CBD	.05	28.16	64.87	410.13	34.75	.00	1209.30	.00	1747.26
UBD	14.48	313.85	1481.32	1699.61	21.37	.00	5728.58	.00	9259.22
URBAN	43.08	1593.62	796.46	8828.22	105.02	.00	9764.55	.00	21130.95
SUBURBAN	8.58	1105.19	458.24	4477.51	284.74	.00	10399.65	.00	16733.93
RURAL	.11	184.75	96.92	2745.25	1.31	.00	2097.40	.00	5125.73
TOTAL	66.30	3226.01	2897.81	18178.47	449.29	.00	29450.31	.00	54268.19

FIGURE 4.25 LINK SUMMARY OUTPUT FROM THE AIRQ PROGRAM

LINK CHARACTERISTICS						LINK PERFORMANCE						VEHICLE ACTIVITY			
LINK	DIST	SP	CAPA	F	A	VOL	CSP	VC	VMT	VHT	VHD	CRUI	ACC	DEC	IDLE
1201 1225	.33	30	650	4	3	507	29.6	78	167.31	5.66	.08	1.23	1.92	.85	1.67
1202 1230	.30	65	3900	2	4	1634	64.3	42	490.20	7.63	.08	3.79	1.90	1.88	.05
1209 1208	.06	65	3900	2	4	2458	60.0	63	147.48	2.46	.19	1.22	.61	.61	.02
121411082	.58	65	3900	2	4	2020	64.4	52	1171.60	18.18	.16	9.04	4.54	4.49	.12
1215 1218	.57	65	3900	2	4	2591	64.5	66	1476.87	22.89	.17	11.37	5.71	5.65	.15
121611116	.35	65	3900	2	4	1867	65.0	48	653.45	9.96	.00	5.01	2.48	2.46	.00
1217 1241	.93	40	1900	7	4	587	39.9	31	545.91	13.70	.05	4.10	5.02	1.82	2.75
1231 1232	.40	65	3900	2	5	3250	63.2	83	1300.00	20.58	.58	10.23	5.14	5.08	.13
1232 1233	2.06	65	3900	2	4	3250	63.1	83	6695.00	106.17	3.17	52.76	26.49	26.22	.69
1240 2181	.57	65	5850	2	4	7403	20.7	127	4219.71	203.58	138.66	70.44	64.74	55.68	12.72
124111105	.81	40	1900	7	4	777	39.8	41	629.37	15.80	.06	4.73	5.80	2.10	3.17
124111118	.21	40	950	7	4	865	36.0	91	181.65	5.05	.50	1.51	1.85	.67	1.01
1242 1291	.05	65	5850	2	4	2018	60.0	34	100.90	1.68	.13	.84	.42	.42	.01
1246 1245	.42	65	3900	2	4	2454	64.6	63	1030.68	15.95	.09	7.93	3.98	3.94	.10
1249 1273	.43	65	5850	2	4	7403	20.8	127	3183.29	153.00	104.02	52.94	48.65	41.84	9.56
1250 1249	.31	40	1400	5	4	1341	35.1	96	415.71	11.85	1.45	6.12	2.86	2.78	.08

FIGURE 4.26 LINK VEHICLE-ACTIVITY OUTPUT FROM THE AIRQ PROGRAM

LINK#: 1202 1230 FACILITY TYPE: 2 AREA TYPE: 4 VHT(Veh-hr): 7.63

TIME-SPENT(Veh-min) BY SPEED(mph) and ACCELERATION(mph/sec)

"MPH"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	TOTAL
0	.0	.0	.0	.0	.0	.0	.0	3.0	.0	.0	.0	.0	.0	.0	.0	3.0
5	.0	.0	.0	.0	.0	.7	1.6	1.8	1.6	.5	.0	.0	.0	.0	.0	6.2
10	.0	.0	.0	.0	.5	.9	1.4	1.8	1.8	.5	.0	.0	.0	.0	.0	6.9
15	.0	.0	.0	.5	.5	.9	1.8	2.7	2.3	.9	.5	.0	.0	.0	.0	10.1
20	.0	.0	.0	.5	.5	.9	2.3	3.2	2.3	.9	.5	.0	.0	.0	.0	11.0
25	.0	.0	.0	.5	.5	.9	2.3	3.7	2.7	.9	.0	.0	.0	.0	.0	11.4
30	.0	.0	.0	.5	.5	.9	2.7	4.1	3.2	.9	.0	.0	.0	.0	.0	12.8
35	.0	.0	.0	.5	.5	.9	3.2	5.0	3.7	.9	.0	.0	.0	.0	.0	14.6
40	.0	.0	.0	.0	.5	.9	4.6	5.0	4.6	.9	.0	.0	.0	.0	.0	16.5
45	.0	.0	.0	.5	.5	.9	4.6	5.5	5.0	.5	.0	.0	.0	.0	.0	17.4
50	.0	.0	.0	.5	.5	.9	10.5	18.8	10.5	.9	.0	.0	.0	.0	.0	42.5
55	.0	.0	.5	.5	.5	1.4	26.1	73.7	26.1	1.4	.0	.0	.0	.0	.0	129.9
60	.0	.0	.0	.0	.0	.9	22.9	73.2	26.1	1.4	.5	.0	.0	.0	.0	124.9
65	.0	.0	.0	.0	.0	.5	8.7	28.8	11.4	.5	.5	.0	.0	.0	.0	50.3
TOTAL	.0	.0	.5	3.7	4.6	11.7	92.6	230.4	101.3	11.0	1.8	.0	.0	.0	.0	457.5

CHAPTER 5

MODEL DEMONSTRATION

The demonstration of the proposed integrated model consisted of the following major steps:

(1) Obtain and make operational the project area network: MTC San Francisco Bay Area network

(2) Review the selected network for the demonstration project, and propose and apply refinements as appropriate

(3) Apply the proposed integrated model to estimate vehicle activity for the existing network, as well as for demand and design alternatives

(4) Analyze the model results to evaluate the effectiveness of the proposed model as an analysis tool for emissions estimation

5.1 The MTC Bay Area Network

The entire MTC Bay Area network was selected for the demonstration of the proposed model. This network was selected over several other candidate regional and local networks because its size and representations of most of the characteristics of the transportation facilities commonly occurring in the field, would allow the evaluation of the full range of capabilities and limitations of the proposed modeling system particularly for large urban areas. The model is well supported by MTC, and there is a wealth of information from various sources about the network characteristics and performance.

The MTC network includes the nine Bay Area counties (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma.) It has been coded for the MINUTP software, and is operational on PC based 3/486 microcomputers. Recently, the MTC model has been updated by adding new traffic zones and links to improve the accuracy of regional forecasts by reducing intrazonal travel, facilitate the modeling of access to rail and other transit modes and the analysis of corridor planning studies. Revisions also were made to link characteristics (distances, free-flow speeds, and capacities.) The network is consistent with the 1990 Census boundaries and the widely used earlier 700 zone MTC network.

The latest MTC network includes 1099 traffic analysis zones and an additional 21 zones as external stations. Each analysis zone includes an average of 1.26 census tracts and population of 5,481 persons; several zones having split census tracts (23,24). There are 26,639 one-way links in the network coded according to an expanded area type/facility type classification (Table 3.4). The number of links per each category are shown in Table 5.1. The 1120 zone network and the trip table for the 1990 am peak period were used as the base conditions for the demonstration of the integrated model.

TABLE 5.1 MTC NETWORK: No. OF LINKS BY AREA TYPE AND FACILITY TYPE

AREA TYPE	FACILITY TYPE Frw-to-Frw (1)	Frw (2)	Exp (3)	Collector (4)	Ramp (5)	Dummy (6)	Major Art (7)	Metered Ramp (8	Totals
Core (0)	0	7	0	272	11	106	451	0	847
CBD(1)	4	30	6	464	43	198	692	0	1437
UBD (2)	45	323	353	1017	300	815	1858	0	4711
Urban (3)	76	597	200	1919	557	1518	2997	0	7864
Suburban (4)	49	867	150	2663	857	2048	3441	0	10075
Rural (5)	8	212	14	691	171	205	404	0	1705
Totals	182	2036	723	7026	1939	4890	9843	0	26639

5.2 Application of the MTC Model

The MTC network and documentation was provided to the research team by MTC and installed on the team's computers. Initial computer runs were made, and the MINUTP outputs were carefully reviewed to verify that the model is working correctly. Any questions on the network coding and the model results were resolved through the model's documentation and contacts with the MTC modeling staff.

Following the initial verification runs, the MTC model was reviewed in detail. The review of the network concentrated on the areas particularly relevant to the demonstration of the proposed integrated model, i.e., i) network coding, and ii) accuracy of the traffic assignment. As it is shown in Table 5.1, the 26,639 network links include 2,218 links representing freeway facilities and 9,843 links representing arterials. Travel on those 12,061 links accounts for about 83 percent of the estimated total vehicle-miles of travel in the MTC Bay Area network. Thus, primary emphasis was placed in the treatment of the freeway and arterial links in the modeling process.

Because of the large size of the network, a special database application was created using the FOXPRO database management program to facilitate the analysis of the results from the various model runs. To create the regionwide database, the network links were written from the MINUTP NETVUE file menu and appended to the database structure created to match the network field structure. Several routines were then written within FOXPRO to produce various tabulations of the network link and node characteristics, and calculate statistics on network variables. Databases containing links of selected freeways and arterials were extracted from the regionwide database by creating auxiliary databases containing the link endpoints (A and B nodes), the freeway and arterial names, street names corresponding to the A/B nodes, and various sorting codes. The auxiliary databases are indexed and matched to the regionwide database, so that link data for each street name pair could be extracted. The resulting databases contain all of the network variables for each link with the identifying street names attached to each record.

5.2.1 Network Coding

The purpose of thoroughly examining the coding of the network was twofold. First, to investigate the level of detail that the various highway facilities have been coded into the model and secondly the accuracy of the specified link types. Both of those elements of model building affect the estimation of the time-spent in each driving mode. For example, coding a series of urban freeway segments with weaving sections as a single link would not permit the use of the appropriate speed/acceleration distributions for each link type. Also, coding an arterial link as suburban area type instead of its correct urban designation would result in inaccurate estimates of vehicle activity.

The specially developed database software was used to extract the links on selected major corridors and plot the corresponding link and node schemes for examining the level of detail in input coding, and the accuracy of the designated link types and other link characteristics. The existing operational data for major corridors in the network (e.g., I-80, I-880, US-101, San Pablo Avenue, El Camino Real, Ygnacio Valley Rd), were used as test cases in the review process. Data from other sources were also used to examine other highway facilities in the network and they were supplemented by field reviews on sample locations to verify the accuracy of coding. This process also served as an indicator to the level of effort required for applying the integrated model, which requires coding the "link type" designation for each link. This step was not required per se for the MTC network because the link types coded would represent a significant portion of the variability in vehicle activity predicted by the simulated link types.

The basic link characteristics coded in the 1990 MTC 1120 zone network include the distance, number of lanes, capacity, facility type, and area type. Supplementary descriptors include geographic location, toll, and "use" (drive alone, HOV1 or HOV2). The link free-flow speed is not explicitly coded. The MTC model uses the area type/facility type designations to determine the free-flow speeds and capacities from a look-up table (shown as Table 3.4), so these parameters can be easily changed between model runs. MINUTP only allows up to 63 different combinations of facility types/area types, which would potentially limit the ability of more accurately describing the link characteristics. This limitation of the software was taken into consideration in reviewing the MTC model coding and offering suggestions for improvements.

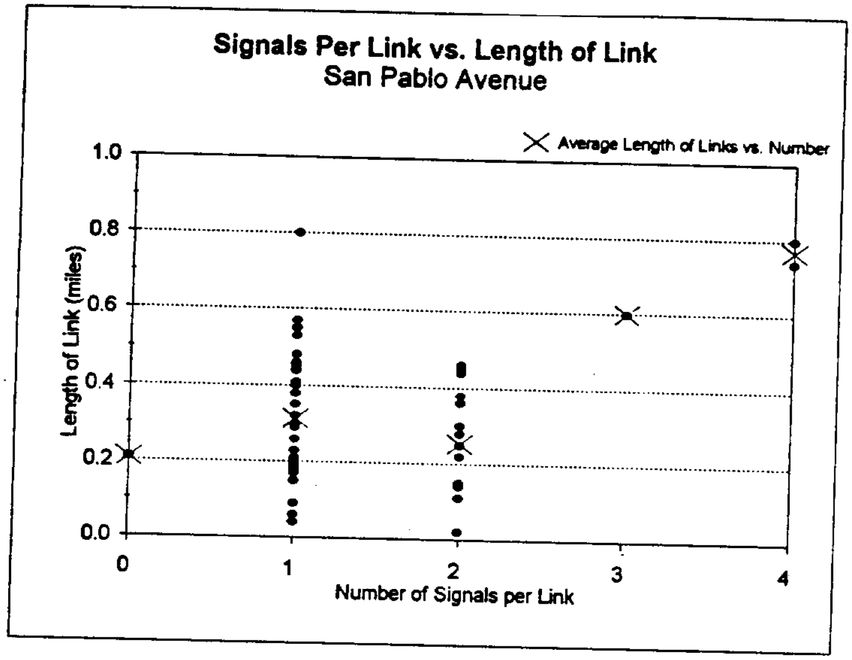
The general accuracy of freeway link characteristics coded for selected freeways appeared reasonable, as did the designation of facility and area type. Most of the freeways in the network have been coded with each ramp junction represented by a different node. However, on several of the freeways reviewed, a few links are coded to represent more than one ramp-to-ramp segment. It is suggested to recode the freeway links on those locations so that each entry or exit is represented by a separate node. This would facilitate the refinement of link type coding and the comparison of predicted volumes and speeds with observed values. The level of the effort for coding the additional links and nodes is expected to be small because only a few locations need to be coded. Also, the increase in computer requirements in terms of storage, memory and computer processing time would probably be insignificant.

The major limitation in the coding of freeway links is the lack of explicit representation of weaving sections. The findings from the analysis of the simulation experiments and field data showed that interchange to interchange links and weaving sections have different proportions of time-spent in each driving mode than straight freeway segments. The MTC model does have a facility type of "freeway-to-freeway" referring to major connectors that would include weaving areas, but there is no specific provision for "weaving type" freeway links in the model. It is suggested to code explicitly weaving areas in the MTC network, especially for urban freeways. This could be accomplished by adding a new facility type with appropriate free-flow speeds and capacities. Alternatively, more refined categories of the same facility type could be coded using variables in MINUTP input deck, that are currently redundant. This information would be sufficient for the NETMRG command file in the AIRQ post-processor to correctly identify the link type. Sufficient space is currently available in the network to define more variables, especially if redundant and unused variables are omitted. Note, that variables not used directly by MINUTP but useful for other reasons might be kept attached to link records in a network database, such the one developed for this study.

The coding of weaving sections in the MTC network is expected to involve a modest level of effort. The priority would be short weaving sections in urban areas, which would require examination of about 1,000 of the total 2,200 freeway links coded. Weaving areas are easily recognizable design characteristics, and no fieldwork is normally required for coding them into the model. Aerial photographs and freeway as-built plans would be an adequate data source for link designation.

The operation and characteristics of arterials have a considerably higher variation that freeways. Facilities with similar geometrics could operate quite differently because of the adjacent land-uses, signal spacing, turning movements at the intersection and signalization (amount of green time to the arterial traffic, and quality of progression.) Also, the vehicle activity could vary significantly between successive segments along an arterial. The existing facility type/area type designation cannot capture such variations on individual links because it does not include the effect of signalization and patterns of entering and exiting flows. Also, several links in the MTC network include segments with more than one signalized intersection. This is illustrated in Figure 5.1 for the San Pablo Avenue (similar or higher proportion of "multi-signal" arterial links was found on other sites). No systematic relationship was found between the coded signals per link and the design and operational characteristics within the same site and among different sites.

FIGURE 5.1 CODING OF ARTERIAL LINKS--MTC 1120 NETWORK



As it was discussed previously in section 4.4 the process of developing the AIRQ post-processor took into consideration the limitations in the coding of arterials in order to produce relationships applicable to the existing state-of-practice in network coding. However, the accuracy of the vehicle activity estimates would be significantly improved if the arterial links in the MTC network would be recoded to provide a better representation of operating conditions. This would also improve the traffic assignment and facilitate comparisons with observed data.

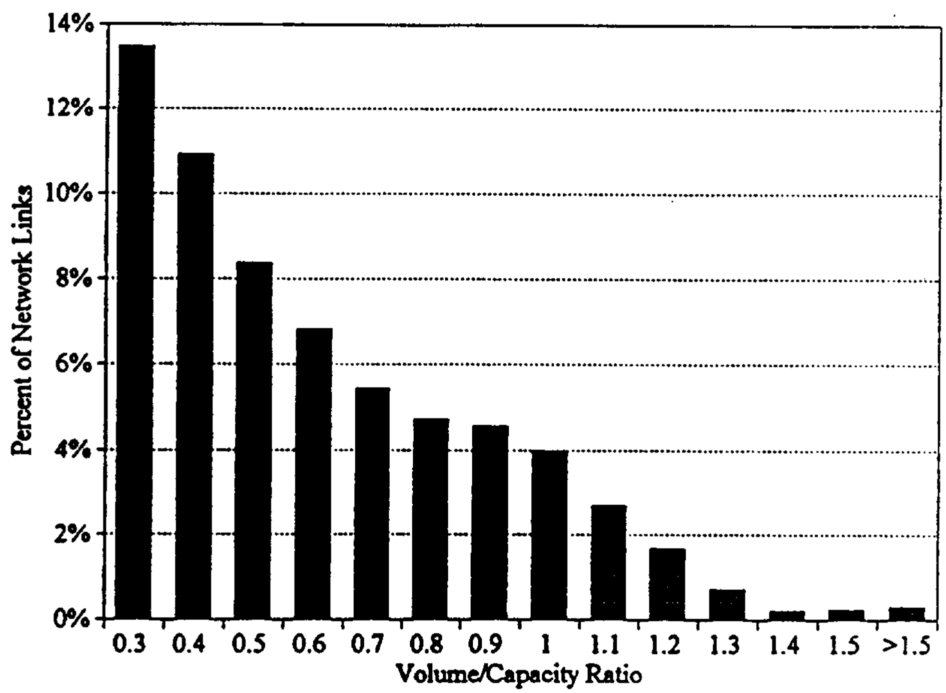
The recoding of arterial links would require substantial level of effort and would also increase in computational requirements for the model execution. Furthermore, it has been argued that this information cannot be accurately predicted for future years and therefore it should not be an input to a planning model. However, in most urban areas the characteristics of arterial corridor have shown incremental changes over the years, and the facility/area type designation does include certain assumptions about future number of signals and other characteristics, which currently are implicit in the model. The explicit coding of such characteristics would better categorize the arterial links and also allow different assumptions to be tested.

Again, recoding may involve additional facility/area types or coding of descriptors on signalization, design quality and traffic patterns to identify appropriate facility "sub-types". Field observations may be required to gather such information. Alternatives to fieldwork for data on signalization and quality of progression includes the information from the FETSIM program, under which 2173 traffic signals along arterials and networks were retimed in 41 cities in the Bay Area. In addition, MTC provides a traffic management assistance program to local agencies under the Intermodal Surface Transportation Efficiency Act (ISTEA), and data on signalization from the participating agencies should be readily available. Those data sources would greatly facilitate the refinement of arterial coding.

5.2.2 Traffic Assignment

The MINUTP model was executed to obtain the baseline volumes and travel speeds for the network links using the default command files for the traffic assignment module provided by the MTC. The results of the traffic assignment are shown in Figure 5.2. Approximately, 10 percent of all the links in the network were at or above capacity. Fourteen percent of the freeway links and 5 percent of the arterial links were saturated. The average travel speed for the entire network is 31.2 mph. The accuracy of the assignment results were examined next by comparing the predicted volumes and travel speeds with observed data.

FIGURE 5.2 RESULTS FROM THE BASE TRAFFIC ASSIGNMENT: MTC Network



Observed traffic volumes were assembled from Caltrans District 4 data and consultant studies conducted between 1989 and 1991. Observed and assigned values for 83 freeway links for which counts were available are shown in Figure 5.3. The diagonal line is the line on which the observed value equals the assigned, the upper is the line on which assigned values are 25 percent greater than observed, and the lower line for the 25 percent below observed. The assigned values are below observed in 40 cases (48%), and above observed in 43 cases (52%). About 19 percent of the data points are more than 25 percent below the observed values, and 15 percent of the estimates are more than 25 percent above the observed value. The largest differences were 84 percent higher, and 45 percent lower than the observed values. Volume comparisons were also made for specific freeways and arterials and similar results were found. Figure 5.4 shows the volume comparison for the I-80 freeway and includes with the locations where the field measurements have been taken. Appendix C includes the list of all the observed and estimated values and additional plots for other locations.

The MTC model predictions is the am peak hour, which represents a rather generically defined peak hour within the 6:00-9:00 am peak period, and not for a specific clock hour. Most of the available traffic counts values were taken from 7:00-8:00 am. Therefore, an exact matching with field observations for particular links during particular hours would not be expected. The primary objective is to obtain a reasonable fit for long multi-link road segments and the entire region.

FIGURE 5.3 PREDICTED .vs. OBSERVED FREEWAY TRAFFIC VOLUMES

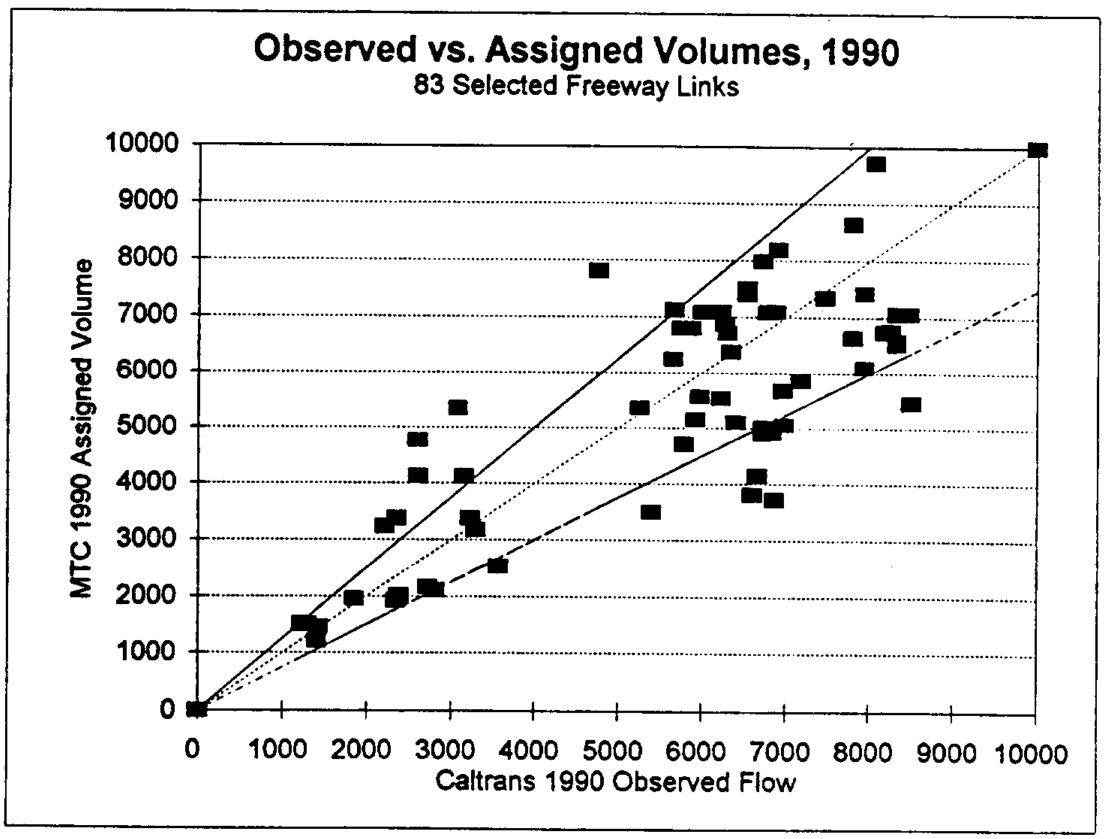
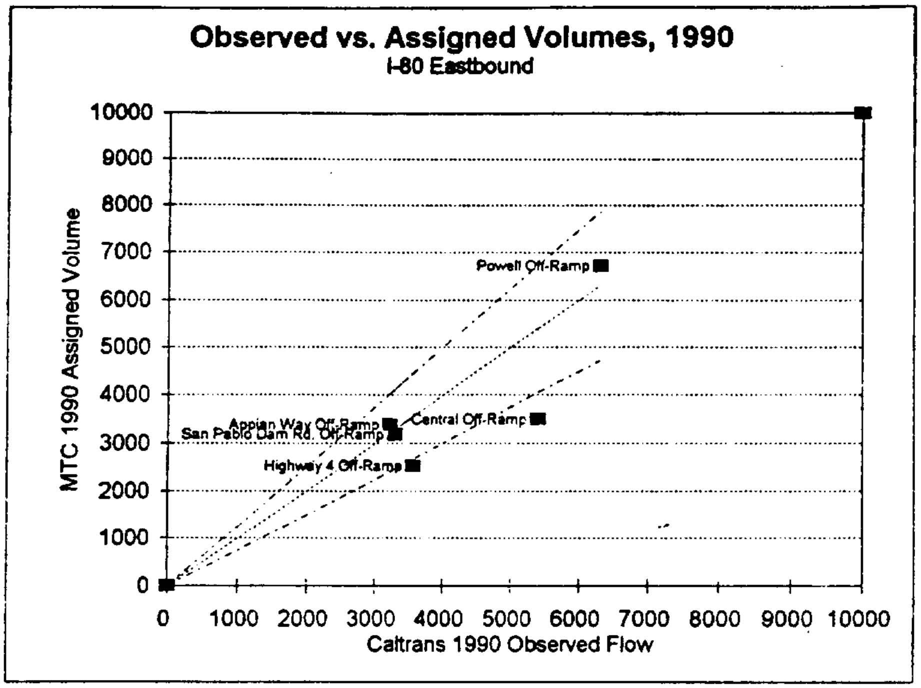
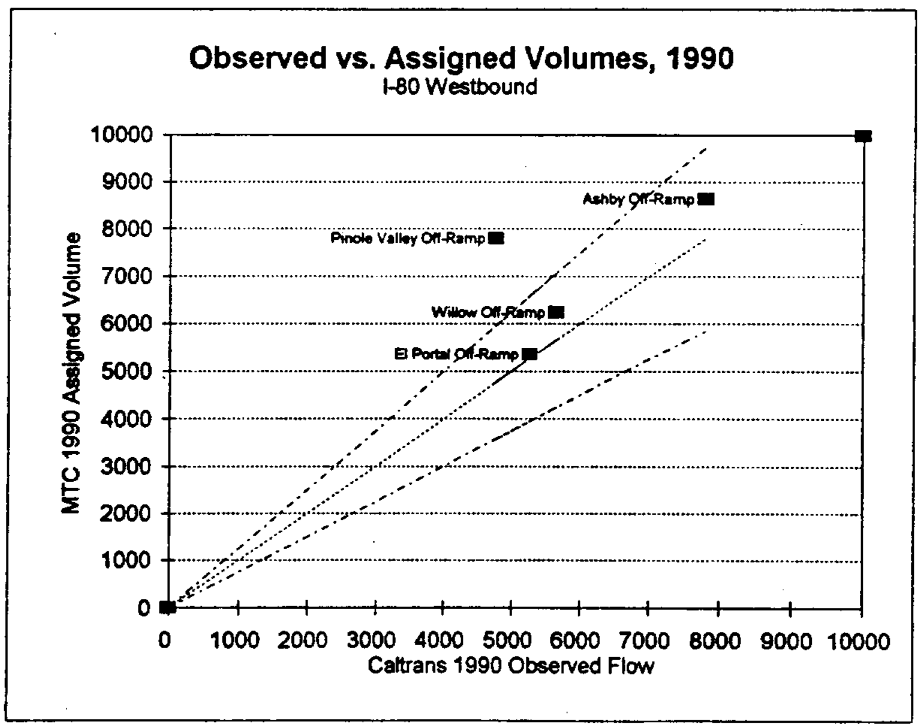


FIGURE 5.4 I-80: PREDICTED .vs. OBSERVED TRAFFIC VOLUMES





Recent field measurements on travel speeds were not readily available except in a few locations. The model speed estimates were evaluated against qualitative information (e.g., congestion maps with speed ranges), and a number of significant differences were found. Several differences were also found between predicted and observed speeds during the testing of alternative speed-flow relationships by MTC staff(29)

The differences found between observed and predicted values are largely due to the basic limitations of the four-step demand modeling process as discussed in Chapter 3, ie., no consideration of queueing in the traffic assignment, time-varying congestion, simplified representation of the highway network, and assumptions about behavioral traveller characteristics. It is important, however, to improve the model predictions within the state-of-practice in regional modeling because the link volume and speed estimates would be used in the calculation of the vehicle activity. Suggested approaches include systematically reviewing the link inputs, adjusting model parameters, and improving the network representation.

Procedures were developed and tested to improve the results of the traffic assignment, as part of the model demonstration within the scope of this study. The following options were applied in the MTC network (proposed in Chapter 3):

- Revised speed-flow relationships
- Queueing post-processor to the planning model

A. Speed-Flow Relationships

The MTC model uses the same speed-flow relationship for both freeways and arterial streets. This relationship included in the first release of the 1120 zone network and the model documentation is a BPR type equation of the form (29):

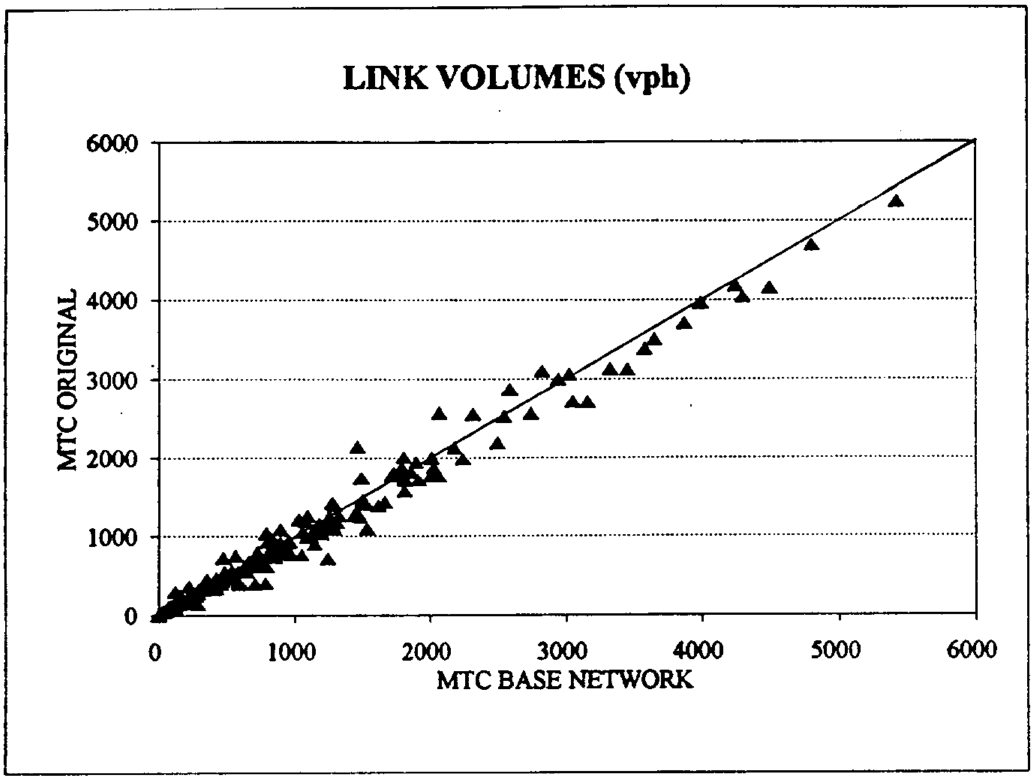
$$V_c = V_o / (1 + 0.45(v/c)^4) \qquad (5\text{-}1)$$

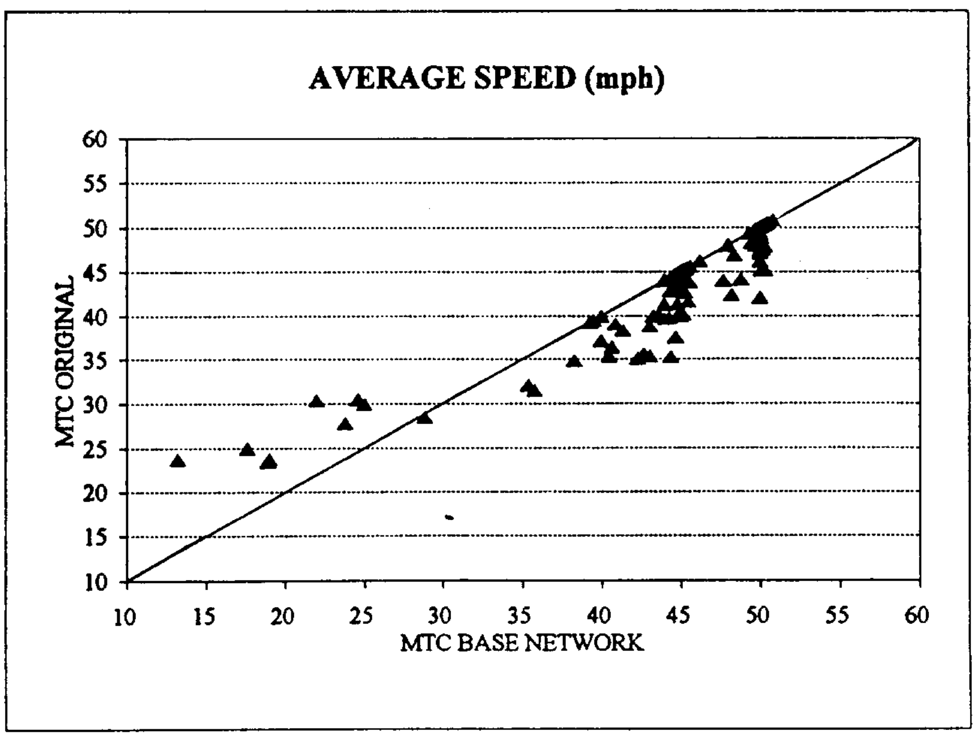
The latest version of the assignment procedure provided to the research team included the following form of the BPR formula:

$$V_c = V_o / (1 + 0.20(v/c)^{10}) \qquad (5\text{-}2)$$

The 1990 MTC network was executed for both types of speed-flow relationships. The results from each run are compared in Figure 5.5 for both the predicted volumes and travel speeds. The new MTC formula predicts higher speeds at v/c ratios up to 1, and lower speeds for higher v/c values which is closer to field data and estimates from operational models. The BPR original formula shown in Equation (5-1) overestimates the speeds at high v/c ratios. The assigned volumes were insensitive to the different speed-flow curves because most of the network links were undersaturated.

FIGURE 5.5 COMPARISON OF THE MTC SPEED-FLOW RELATIONSHIPS





Next, alternative speed-flow relationships for each link type were derived from the analysis of the INTRAS and TRAF-NETSIM model runs performed to generate vehicle activity data. The average speeds predicted from the microscopic simulation models on the selected sample networks were plotted against the v/c ratio and various speed-flow relationships were fitted to the simulated data. Sample results from two arterial test sites are shown in Figure 5.6, together with the speed-flow relationships used in the MTC model. The analysis of the results indicate that the following expression for the speed-flow curve would provide a better fit the simulated data:

$$V_c = KV_o/(1+(v/c)^{10}) \tag{5-3}$$

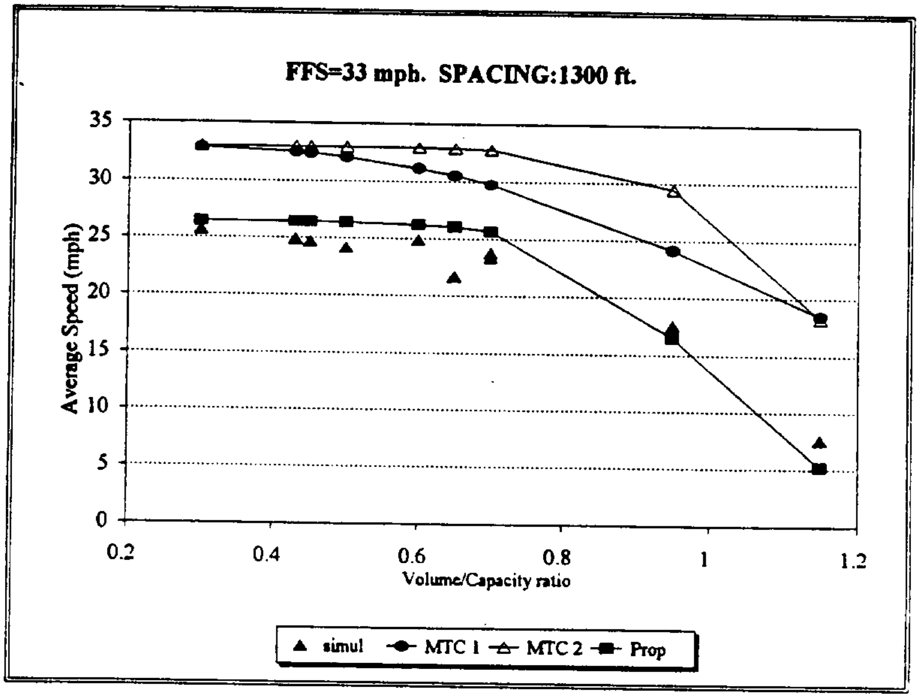
where:
K: 1.0 for freeways
: 0.8 for major arterials
: 0.6 for short spaced dense networks

The proposed speed-flow relationship given in (5-3) predicts lower speeds than the curve used in the MTC model for v/c ratios higher then 0.8 with a speed of 30 mph. at capacity. Recent research for updating the analysis procedures in the Highway Capacity Manual (37) indicate that speeds on uninterrupted flow facilities such as freeways and multilane highways remain essentially constant until capacity is reached, (speed of 50 mph. and v/c=1), and then drop sharply to 25-35 mph. following the onset of congestion depending on the location of the field measurements. The MTC curve agrees with these findings for v/c up to 1, but tends to overpredict travel speeds at higher v/c ratios. The proposed relationship in contract appears to predict speeds closer to empirical observations for saturated conditions, but umderpredicts speeds for v/c

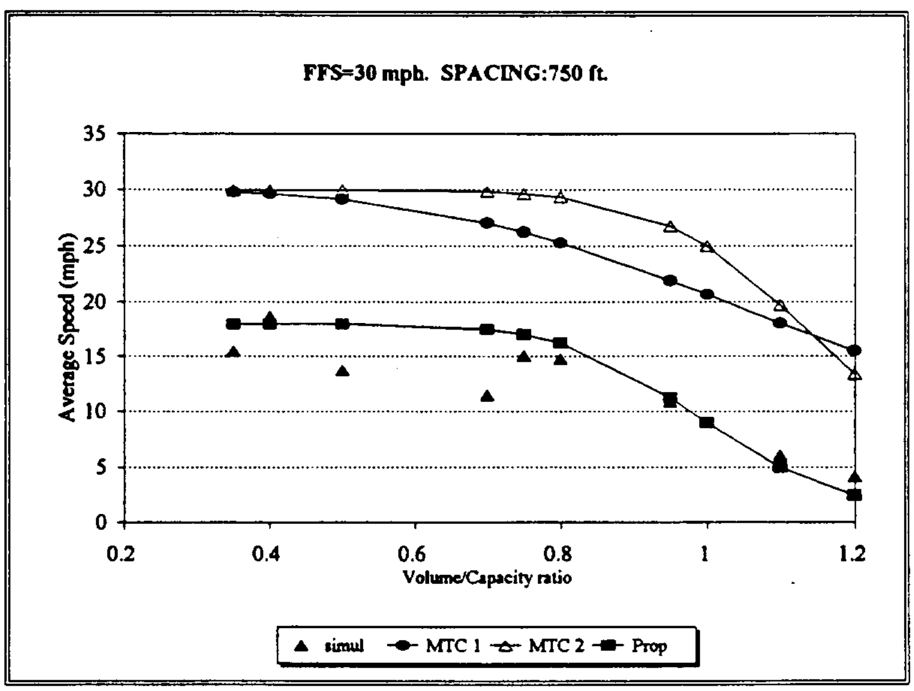
The MTC model was run using the proposed curve with K=0.8 for all the links and the speeds were compared to the values from both the base run and field measurements on 119 links provided by MTC (Table C.2 in Appendix C.) The results showed that the speeds was closer to the field data on 67 of the links, the MTC run was closer to 45 links and the values were the same on the remaining 7 links. The MTC run, however, had a lower root mean square (RMS) error because the proposed speed-flow curve predicts very low speeds on a few saturated links.

Other options for improving the speeds estimates include a) using different flow curves for freeways and arterials, e.g., the curve given by (5-2) could be used for freeways, and the curve given by (5-3) for arterial streets, and b) use a BPR type curve for v/c ratio up to 1 and a different curve for saturated conditions. Final determination of the speed-flow curve should be based on thorough comparisons with field measurements particularly for saturated conditions.

FIGURE 5.6 LINK SPEED FLOW RELATIONSHIPS
A. San Pablo Avenue, Berkeley



B. Ygnacio Valley Rd (Urban Section), Walnut Creek



B. Queueing Post-Processor

The queueing post-processor is a procedure developed by members of research team (6) that is applied at the end of the assignment step of MINUTP to improve the speed estimates for oversaturated links (links with v/c ratios in excess of 1.) The post-processor uses a BPR type speed-flow curve and a simple queueing analysis model. The queueing model determines the number of vehicles in the queue and the proportion of the link that is congested. The average link speed is then calculated from the speed derived by the speed-flow relationship and the queue speed (normally the speed at the density of 25 ft/vehicle.) The calculations are carried out in time slices (e.g., hourly time-slices to study daily estimates) and averaged over the analysis period. Comparisons with estimates from traffic operations models have shown that this procedure produces more realistic speed estimates than the original planning models.

The following modifications and enhancements were made to the original queueing post-processor in order to be applied to the MTC 1120 zone network:

- User defined speed-flow curve: the original post-processor was using the speed-flow curve based on Equation (5-3) with K=1. The modified post-processor allows the user to specify all the parameters *(K, a, b)* in the speed-flow curve. This permits to evaluate the effects of queueing on the estimated speeds for the same speed-flow curve on both the MINUTP and post-processor.

- Peak-hour volumes: The original post-processor was developed for analyzing loaded networks reporting average daily traffic. The 1120 zone MTC network used in this study produces am peak hour volumes. Therefore, the post-processor was modified to model the entire am peak period (5:00-11:00 am) in successive 1 hour time slices. The portion of the traffic volume in each time slice was determined based on the 1981 MTC travel survey which reports hourly volumes for the entire region over the 24 hour period and using the 7:00-8:00 am period as the peak hour.

- Coding free-flow speeds: As it was mentioned in Section 4.4, the link free-flow speeds are not explicitly coded in the MTC network. Those were determined in the queueing post-processor based on the facility type and area type designations using the same procedure as in the AIRQMTC.SET routine.

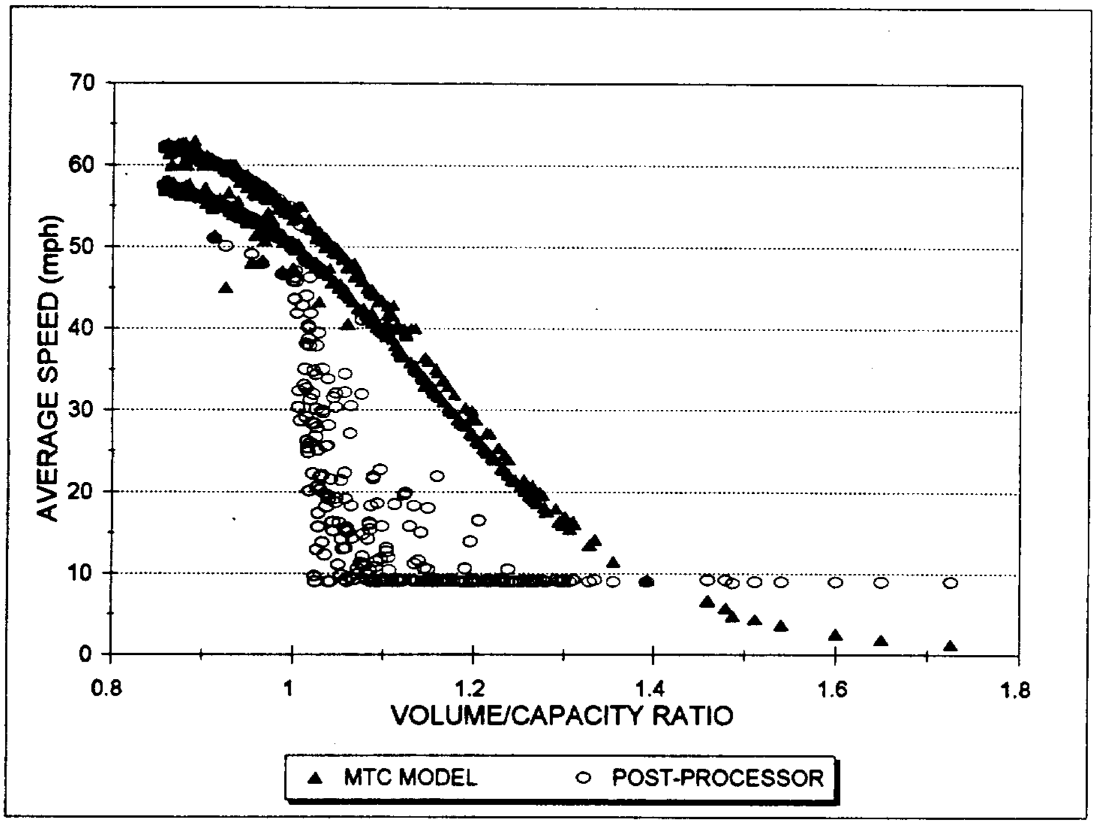
Figure 5.7 shows the predicted speeds for the freeway links from the base run of the MTC network and the speeds estimated from the queueing post-processor, for v/c ratios higher than 0.8. The same speed-flow relationship was specified on both the base run and the post-processor. The average speeds as expected are the same for v/c ratios up to 1. For congested links, however, the post-processor predicted speeds are lower than the MINUTP speeds reflecting the presence of queueing, and the differences in link speeds for the same v/c ratio depend on the proportion of congested link, i.e., the link length. Note, that the queueing post-processor does not adjust the estimated link volumes.

The simple queueing model in the post-processor does not account for queues extending upstream of the specific link, and the metering effects of the congestion for the downstream links in the network. Also, the queues remaining at the end of the last time slice in the analysis period are not included in the computations. If observations indicate that congestion has dissipated at the end of the peak period, then peak hour spreading is likely to occur and the peak hour factors would have to be adjusted which would in turn affect the estimated average speeds.

The queueing post-processor is written as a command file using the NETMRG commands of MINUTP, and it can be executed from within the typical setup for a planning model assignment run. Outputs include link volumes and speeds, and tabulations of VMT and VHT by facility type and average travel speed at 5 mph intervals. The listing of the program is included in Appendix F.

FIGURE 5.7 QUEUEING POST-PROCESSOR vs. MTC BASE NETWORK SPEEDS

Freeway Links with Volume/Capacity > 0.8



5.3 Estimation of Vehicle Activity

The AIRQ post-processor was applied to the MTC 1120 zone network for the AM Peak hour 1990 traffic conditions to estimate the time-spent in each driving mode based on the MINUTP assignment provided by MTC. The application of the proposed model was straightforward. Most of the effort was to determine the equivalent link types as described in Section 4.4. The execution time of the program was approximately 7 minutes in a 486 microcomputer. A total of 19018 links were processed out of the 26639 links in the MTC network. The rest of the links were dummy--centroid connectors--links, and links with zero assigned volumes that were excluded from processing. Model runs were also made using the 700 zone MTC network for the 2010 traffic conditions (an 1120 zone 2010 network was not available at the time of the study.)

Figure 5.8 shows the networkwide predicted values of time spent in each driving mode per speed/acceleration category, and the network summary statistics for the 1990 network. The same tables were produced for each facility type. About 34 percent of the total time was spent in cruse, 47 percent in acceleration/deceleration and 19 percent in idle mode. The time spent accelerating/decelerating in the range -2 to +2 mph/sec accounts for 83 percent of the vehicle activity in the acceleration/deceleration mode. Total delay accounted for 35 percent of the total travel time in the network. Most of the delay occurred on the saturated links and the average delay was 0.68 min/veh-mile.

The vehicle activity estimates shown in Figure 5.8 are for the typical am peak hour based on the MINUTP assignment for the network. The model can be applied to obtain estimates of vehicle activity for other time periods as follows:

(1) Develop trip tables for each analysis period from the daily zone-to-zone trip matrix using volume adjustment factors (e.g., peak hour factors for the pm peak hour.) These factors are normally determined from household travel surveys and other empirical data.

(2) Run the assignment module of MINUTP with the trip tables developed in Step (1) to produce a loaded network with assigned volumes for each analysis period.

(3) Run the AIRQ software for each loaded network to obtain vehicle activity data. Aggregate the results from all the runs to determine the total time spent for the entire period of analysis.

The User's Guide (Appendix B) provides specific instructions for performing multiple model runs, and to run the AIRQ post-processor with the same computer setup used for the MINUTP software.

FIGURE 5.8 PREDICTED VEHICLE ACTIVITY: MTC 1120 ZONE NETWORK

AM Peak Hour--1990 Base Conditions

VEHICLE ACTIVITY FOR THE TOTAL NETWORK
TIME-SPENT (Veh-hr) BY SPEED(mph) and ACCELERATION(mph/sec)

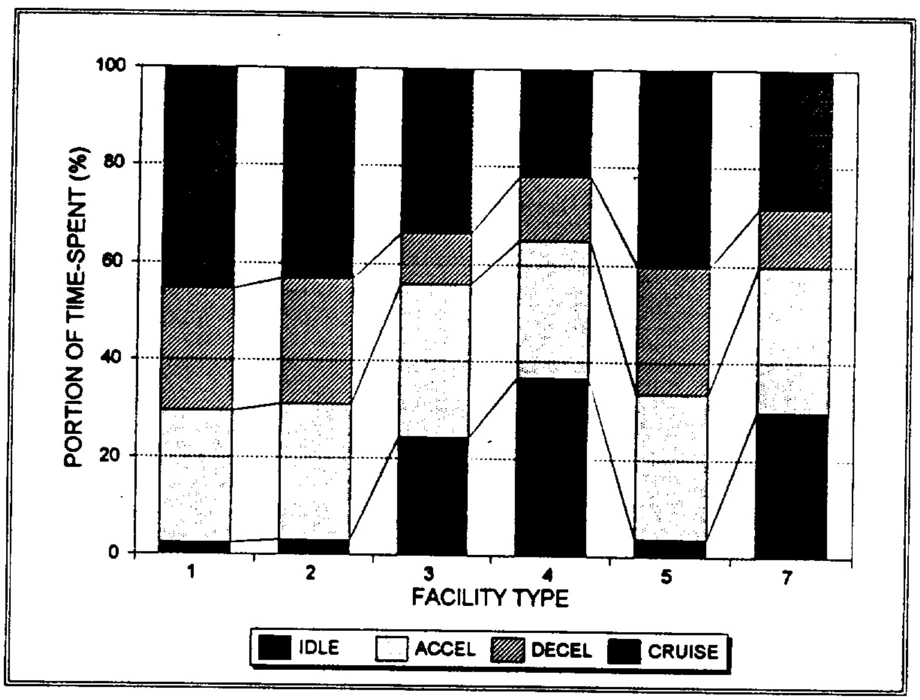
"MPH"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	TOTAL
0	.0	.0	.0	.0	.0	.0	.0	54268.2	.0	.0	.0	.0	.0	.0	.0	54268.2
5	.0	.0	398.0	100.7	94.1	2257.4	2434.2	11882.9	2233.4	756.1	621.7	263.9	1230.4	38.8	.0	22311.8
10	.0	.0	146.5	194.1	627.0	1755.6	1708.0	2742.9	2073.5	793.5	823.7	1130.6	482.4	201.4	.0	12679.1
15	.0	.0	188.6	710.5	610.6	1444.1	1713.3	2547.2	1919.6	689.4	1569.1	978.0	231.5	268.9	.0	12870.9
20	.0	.0	209.3	929.5	539.8	1568.8	1877.6	2594.8	2430.1	1328.8	3393.3	182.9	69.5	183.5	.0	15307.9
25	.0	.0	164.4	684.6	382.5	1429.0	1997.9	5163.5	5625.5	2542.0	1457.4	22.1	18.6	50.5	.0	19538.1
30	.0	12.2	173.7	583.4	365.1	995.5	2818.5	13992.3	11068.9	2167.8	299.1	1.8	.0	16.7	.0	32495.1
35	.0	.0	78.2	303.9	293.7	747.0	2134.1	10407.8	8996.2	762.5	142.8	12.2	.0	.0	.0	23878.3
40	.0	.0	30.7	92.2	97.9	362.4	1708.5	6004.5	4928.3	438.4	23.0	.0	.0	.0	.0	13685.8
45	.0	.0	9.0	120.9	69.7	293.4	1389.7	4087.9	2746.6	192.0	7.9	.0	.0	.0	.0	8917.1
50	.0	.0	7.2	68.0	63.6	196.6	2300.0	6536.0	3230.9	170.4	1.4	.0	48.2	.0	.0	12622.3
55	.0	48.2	108.6	108.6	60.4	229.4	5564.5	13195.8	5419.8	277.6	.0	.0	.0	.0	.0	25013.0
60	.0	.0	.0	.0	.0	120.8	4032.5	12170.8	4744.6	277.6	156.9	48.2	.0	.0	.0	21551.4
65	.0	.0	.0	.0	.0	60.4	1195.7	4287.1	1654.5	108.6	108.6	.0	.0	.0	.0	7414.9
TOTAL	.0	60.4	1514.1	3896.4	3204.6	11460.6	30874.4	149881.7	57072.0	10504.8	8604.9	2639.6	2080.6	759.9	.0	282554.1

NETWORK SUMMARY STATISTICS

TOTAL DISTANCE TRAVELED (VMT):	8814993.0
TOTAL TRAVEL TIME (VHT):	282552.0
TOTAL DELAY (VHD):	100137.9
AVERAGE NETWORK SPEED (MPH):	31.2

Figure 5.9 shows the proportion of the total travel time spent in cruise, acceleration, deceleration and idle modes per each highway facility type in the MTC base network. They were no facility type 8 links (metered ramps) coded in the network, and dummy links (facility type 6) were excluded from processing. Vehicles on freeway facilities (fac. type 1&2) spend about 45 percent of the time in the cruise mode with less than 3 percent of the time idling. On arterials by contrast the time spent in idling accounts for 30 percent of the total travel time. Based on the model results, about 39 percent of the total vehicle hours of travel were spent on freeway facilities and 35 percent on arterials.

FIGURE 5.9 PROPORTION OF THE TIME-SPENT BY MODE
MTC 1120 zone Network AM Peak Hour--1990 Base Conditions



The model demonstration using the MTC network, verification of the model output, comparison with the MINUTP estimates and other tests show that the proposed model is working correctly and can be used as a tool to provide vehicle-activity data for regional areas, and to determine the impacts of demand growth and/or design and management scenarios in a network within the state-of-practice in regional transportation modeling. It should be also recognized that the accuracy of the AIRQ model estimates depend on the link type specification and the output from the MINUTP network assignment.

CHAPTER 6

CONCLUSIONS

6.1 Summary of the Study Findings

There is a need for improved techniques for estimating air pollutant emissions from motor vehicles, and assessing the effectiveness of emission control measures. A full understanding of the mobile source emissions burden requires the estimation of the time-spent in each driving mode. The purpose of this study was: i) to evaluate the feasibility of applying network simulation techniques in conjunction with the traditional four-step planning models for determining the vehicle activity in large urban areas, ii) develop an integrated model based on the most promising modeling approach, and iii) demonstrate the application of the model in a large metropolitan area.

The study methodology consisted of critical review of the state-of-the-art planning and simulation models, formulation and assessment of alternative approaches for the integrated model, development of the model and software implementation, and demonstration of the model using the entire MTC San Francisco Bay Area network. The end products of this study are:

a) A model to estimate the time-spent in each driving mode based on relationships between basic link characteristics and vehicle activity. The model has been implemented as a post-processor to the MINUTP planning model.

b) Procedures and recommendations for applying existing regional models for emissions estimation and air quality analysis, and suggestions on developing new techniques to overcome the deficiencies in the existing methodologies.

The major findings and recommendations from the study are presented below:

6.1.1 Feasibility of an Integrated Model

The estimation of vehicle activity by mode of operation requires the application of both planning and simulation models. The four-step planning models provide the input traffic volumes and turning movements to microscopic network models, which in turn simulate the characteristics of individual vehicles and their trajectories in the network. TRAF-NETSIM and INTRAS are the only models that can provide the information to determine vehicle activity in a network and they were selected along with the widely used MINUTP regional model as components of an integrated modeling system. Three alternative approaches that met the project objectives were developed for an integrated model:

The first approach consisted of sequentially linking the MINUTP with the microscopic models. This process requires detailed operational data and recoding of the network in sufficient detail for the microscopic models. Also, the assigned volumes from

MINUTP are often unrealistic because planning models do not consider queuing in the traffic assignment. This model is best suited for subarea analysis, because at present it is computationally infeasible to simulate microscopically traffic conditions in large areas such as urban counties. The implementation of this approach would require development of model interfaces and modifications to the simulation models' source code for greater computational efficiency and handling of large networks.

The second approach also involved the linkage of the planning and simulation models. However, it proposed to use the travel times from the simulation models back into the MINUTP assignment algorithm. This iterative process would improve the accuracy of the planning model' volume and speed outputs. Several ways were investigated to implement such a procedure and a special version of the simulation model was formulated for use in the assignment process. This approach involved challenging software development, and also it has the same shortcomings as the first approach regarding the data collection and network coding requirements, and its application to large networks.

The third ("sampling") approach involves the stratification of the network links into distinct "link types" depending on facility type, design, traffic and control characteristics. The time-spent in each mode is estimated from the link volume and travel time outputs from the planning model and relationships between the link types and vehicle activity. These relationships would be developed through simulation in small scale networks with the selected link types. This approach produces regionwide estimates of vehicle activity data, and would be implemented as a post-processor to the MINUTP and run on PC based 3/486 microcomputers. Recoding of the network is not required except of coding additional fields in the link data file to designate the link types. The accuracy of this approach depends on the planning model estimates and the extent of the representation of the link characteristics into the analytical relationships.

The evaluation of the alternative modeling approaches considered the accuracy of their predictions, range of applications, data input and coding requirements, software modifications, computational resources, and overall cost-effectiveness. The sampling approach had the highest cost-effectiveness because it provides regionwide estimates of vehicle activity and it can be applied with the existing state-of-practice in regional modeling.

6.1.2 The Proposed Model

The first step in developing the integrated model based on the sampling approach was the selection of link types, recognizing the fact that it is practically impossible to capture all the variations in the characteristics of the different highway facilities into separate categories. The determination of link types considered the accuracy of the relationships, time and computational resources to develop the relationships, data collection and coding requirements to implement this approach in the planning model, and the link classification schemes commonly employed in regional models. A total of 39 link types were proposed for developing relationships through simulation.

A database with real-world test sites of freeway sections and surface streets was assembled. Twelve surface street data sets (eight arterials and four grid networks,) and two freeway corridors were selected as the test sites for the simulation experiments to generate vehicle activity data. The data sets were carefully chosen to provide a sufficient sample of the selected link types and of the conditions commonly occurring in the field. Next, routines were written to calculate the time-spent in each driving mode from the vehicles' trajectories outputs provided by the simulation models.

The process of generating vehicle activity data through simulation in the selected data sets was a large and complex modeling exercise. First, the data were coded into the TRAF-NETSIM and INTRAS models and several initial runs were performed to verify the accuracy of the coding and the stability of the results. Next, base simulation runs were performed in each site and the outputs were processed through the software to determine vehicle activity. The process was repeated on each site by changing the input volumes to obtain performance estimates for a range of volume-to-capacity ratios. Additional simulations were performed to determine vehicle activity for scenarios not sufficiently represented in the test sites (e.g., different signalization conditions on surface streets and alternative designs on freeway segments). In addition, the trajectories of instrumented vehicles from actual floating car runs on the I-880 freeway were analyzed to compare the measured time-spent in each driving mode with the predictions of the INTRAS model. The simulation results were analyzed on each site separately for each link, portion of the network (e.g., arterials vs. cross-streets,) and for the entire network.

On straight urban freeway sections, the proportions of time spent in cruise, acceleration, deceleration and idle modes were constant with minimal "stop and go" vehicle activity for a wide range of traffic volumes up to the capacity, with vehicles traveling close to free flow speeds. When demand reaches or exceeds capacity, however, there is a significant increase in the time-spent in slowdowns and stop and go traffic conditions. Similar results was found for freeway sections typical of suburban/rural operating environments except of higher average speeds under free flow conditions, because of the higher design standards. Freeway weaving sections in urban areas had significantly higher proportions of time in accelerations, decelerations and idling even for uncongested conditions because of the complex vehicle interactions and intensive lane changing maneuvers that must be performed in a limited area. Vehicle activity on those facilities strongly depends on the design characteristics, with longer weaving areas having similar vehicle activity as the basic freeway sections.

The largest variation in vehicle activity on surface streets for undersaturated conditions was found in the percent of time spent in cruise and idle modes. The proportion of time spent in acceleration and deceleration was similar in all the networks. The time-spent in cruise and idle modes depends on the average signal spacing, amount of the green time for the arterial through traffic and the quality of progression. Also, the proportion of time-spent at each speed interval depends on the variation of the signal spacing along the arterial. The configuration of the network (grid vs. arterial) is significant only for CBD/downtown areas. On those networks a significant amount of time is consumed idling and at low travel speeds because of the short intersection spacing and numerous vehicle/pedestrian conflicts at traffic signals. Suburban grid networks in contrast have similar patterns of vehicle activity as the arterials. Most of the time is spent in the idling and acceleration and deceleration modes under oversaturated conditions in all the test sites.

The predicted link vehicle activity data from the simulations on each test site were analyzed to determine the time-spent per driving mode for each of the proposed link types shown in Table 3.3. These estimates were further analyzed to determine significant differences in the time-spent estimates within a link type and across the link types. The analyses and comparisons on vehicles activity analyses were performed for links representing single segments (e.g., a street segment between two signalized intersections) and for links consisting of several road segments. This process produced a set of relationships defined by the link type, the v/c ratio, and the free-flow speed. These relationships account for the variation of vehicle activity between facility types, undersaturated vs. oversaturated conditions, and characteristics within a link type.

These relationships were then incorporated in a specially written post-processor to the MINUTP planning model. The post-processor consists of two main modules. A MINUTP/NETMRG command file to process the output from the planning model and produce a file with link characteristics for input to the AIRQ computer program. AIRQ then calculates the time-spent in each driving mode based on the proposed relationships. The post-processor could be executed as part of the typical setup of a planning model run, or in interactive menu driven mode. The post-processor produces the following outputs:

- Tables with time-spent in each speed-acceleration category for speeds 0-65 mph (at 5 mph) intervals and accelerations from -7 to +7 mph/sec (at 1 mph/sec intervals), for each link, facility type and the total network. This information can be used directly to estimate emissions using modal emission factors.

- Summary of the vehicle activity and traffic performance for each link, facility/area type and the total network, including VMT, delay, average speed, travel time and the total time spent in idle, acceleration, cruise and idle mode. This information can be used to estimate emissions based on simplified modal emission factors (e.g., idle, cruise, stop-to- and-from), and speed based emission rates.

6.1.3 Demonstration of the Model

The model was applied to the entire MTC San Francisco Bay Area network. This network includes a total of 1120 zones, 15,000 nodes and 26,639 links. The AM peak period for the 1990 year was used as the basis for the model runs. The findings from the application of the model are summarized below:

Data collection/coding: The major activity performed was to convert the proposed link types into the equivalent link types based on the scheme used by MTC--link classification by facility type and area type--to avoid recoding the links in the network in order to apply the proposed model. The MTC link categorization provides sufficient link classification to permit the conversion process. However, detailed review of the link coding in the model identified a number of deficiencies related to the application of the proposed model. These include lack of information on the link data records about weaving sections and arterial progression quality, as well as not systematic way of coding arterial sections. Recommendations were provided for improving the network coding without extensive network modification.

Planning model accuracy: Comparisons with existing field data found several differences between the estimated and observed values of traffic volumes and speeds. There is a need for systematic calibration and validation of the model before it is applied to produce vehicle activity data. However, there is a lack of data readily available for comparison with the model results. It is recommended to assemble and collect performance data at sufficient locations to permit a thorough calibration and validation of the model. Note that data exist from several sources but there are fragmented and not easily accessible. For example, several Bay Area local agencies have conducted travel time studies on arterials as part of the California's FETSIM program. A number of local agencies also collect travel time information on major corridors to monitor and evaluate congestion management strategies (CMS). Such data would be extremely useful in the calibration/validation of regional models.

Several proposals were developed and tested to improve the MINUTP modeling process. It is suggested to replace the common BPR equation used in the assignment for all the facilities by speed-flow relationships specific to facility types, and proposed forms of the speed-flow curve were generated from the simulations on the selected data sets. It is also recommended to use the queuing post-processor to improve the estimated travel speeds by MINUTP. The queuing post-processor does not change the assigned volumes; it provides speed estimates closer to the ones obtained from detailed operational models to improve the accuracy of the vehicle activity estimates. Again, availability of data on average travel speeds would provide insights on the effectiveness of the proposed procedures.

Proposed model application: The application of the proposed model was straightforward. It was necessary, however, to modify the MINUTP command file of the post-processor to code the free-flow speeds that are not coded in the MTC model based on the area type and facility type designations. The execution time of the program was approximately 7 minutes in a 486 microcomputer for the entire MTC network. Verification of the model output, comparison with the MINUTP model estimates and other tests indicated that the proposed model is working correctly and can be used as a tool to provide vehicle-activity data for regional areas.

The application of large scale models such as the MTC network would be greatly facilitated by creating database systems such as the one developed by the research team. Such software implementations greatly facilitate the storage and manipulation of data multiple network runs, and comparisons with field data at spot locations identified only by street names. Also, information from other analysis tools, such as post-processors, can be incorporated readily into the databases, if the records contain node numbers and can be written in ASCII or SDF format. Furthermore, the databases can store information about links not used by the planning models in particular model runs allowing flexibility in specifying link attributes between runs. The databases created for this study the regionwide databases of about 25000 links each for the MTC 1120 and 700 zone networks as well as selected major Bay Area corridors are available.

6.2 Future Research

Accurate estimation of vehicle emissions is a critical element in air quality analysis. The proposed model developed in this study improves the current state of the emissions estimation process. However, further research and development activities are needed in several areas to develop new techniques. These are given below:

- **Integrated Model:** There is a need for developing a truly integrated model as described in Chapter 3 for simultaneously forecast the traffic volumes and speeds and determine the time-spent in each driving mode. The model would be based on the same basic principles of interaction between detailed simulation and planning models to estimate the time-varying assignments of congestion as proposed in the second model alternative developed in this study. However, it is possible to reduce substantially the computational requirements through a self adaptive discretization of the study area, so areas not directly affecting the performance of the network of interest would be "buffer" networks and simulated in coarser level of detail. This approach coupled with the continuous technological advancements in computer technology would make this type of model feasible for entire regions. It is proposed to further develop the methodology for designing and implementing such a model.

- **Data Requirements and Management:** Lack of data leads to input coding simplifications and inaccuracies, and not properly calibrated and validated planning models. However, as it was previously mentioned several data do exist from numerous transportation and development projects that are normally kept in several locations and are practically inaccessible. However, the ongoing and soon to begin projects of applying information technologies as part of the IVHS activities would create several databases that can be directly used for modeling purposes. Such data would represent peak period traffic conditions on major transportation corridors, including volume information from loop detectors at the traffic operations centers, and travel time and origin-destination information from in-vehicle route guidance systems. For example, in the San Francisco Bay Area, the freeway service patrol (FSP) vehicles are equipped to collect travel time information on congested freeways automatically. Soon to begin is also the Trafinfo project concerned with information exchange for travel purposes. Therefore, the critical need is not the data collection per se, but the access and management of existing data so they can be easily accessible for modeling and analysis purposes. Comprehensive database management procedures are needed to access, organize and correlate such information within the existing regional MTC transportation modeling system as well as other regional models.

- **Regional Modeling Process:** There are several weaknesses in the current sate of regional transportation modeling practice particularly related to air quality analysis. This study placed major emphasis in the limitations of the traffic assignment step of the planning models as relate to the speed estimation. There are several other modeling aspects however, that need to be considered for evaluation of transportation measures as related to emissions, including: relationship between land-use and transportation models, peak spreading, representation of the vehicle mix (particularly in corridors with heavy truck traffic.), improved modeling of HOV lanes, and seasonal variations.

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APPENDIX B. USER'S GUIDE FOR THE AIRQ SOFTWARE

TABLE OF CONTENTS

B.1 Overview

The AIRQ software is a post-processor to the MINUTP four-step planning model. It calculates the time-spent in cruise, acceleration, deceleration and idle modes in a regional network, from the link volumes and speed output from MINUTP assignment and relationships between link characteristics and vehicle activity. The process for developing and the basic computational steps of the post-processor are described in Chapter 4 of the report. This User's Guide describes the steps for running the software, and provides examples of its application.

The post-processor to the MINUTP model is operational on PC based 3/486 microcomputers and consists of two main modules. The AIRQ.SET command file to process the MINUTP model output, and the AIRQ computer program written in Microsoft FORTRAN 5.1 to estimate vehicle activity. Figure 5.1 shows the data flow for the AIRQ software. First, run the MINUTP assignment module to create a loaded network with assigned volumes and speeds. The AIRQMTC.SET command file (implementation of the AIRQ.SET file for the 1120 zone MTC network,) processes the output and creates a link data file for the AIRQ program. The AIRQ program can be executed either in batch or interactive menu driven mode to produce vehicle activity estimates and performance measures for each link and the total network.

It is assumed throughout the description and instructions for the AIRQ software that users are familiar with the basic commands of the DOS operating system, editing of text files, and the MINUTP software.

B.2 Software Installation

The AIRQ software is provided in a single 3.5" high density diskette, and consists of the following nine files:

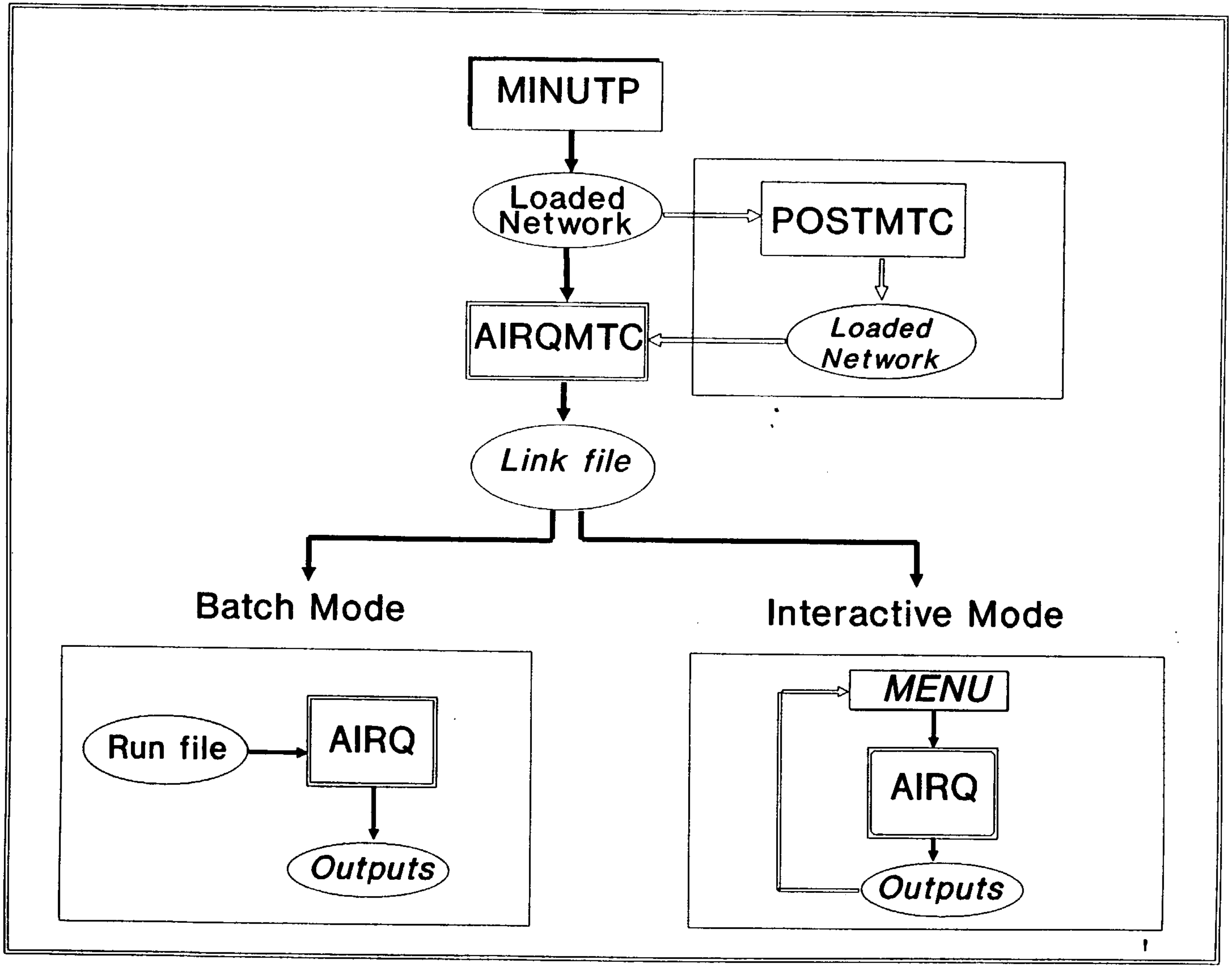
TABLE B.1 CONTENTS OF THE SOFTWARE DISTRIBUTION DISK

1. **READ_ME.FIL:**	Contents of the software distribution disk
2. **AIRQMTC.SET**	Command file for processing MINUTP output
3. **AIRQ.BAT**	DOS batch file for interactive run of AIRQ program
4. **AIRQI.EXE**	Executable file for interactive run of AIRQ program
5. **AIRQTBL.TBL**	ASCII text file with link/veh-activity relationships
6. **AIRQO.EXE**	Executable file for running AIRQ in batch mode
7. **AIRQ.FIL**	Sample run file for running AIRQ in batch mode
8. **AIRQINP.INP**	Sample link input file for the AIRQ program
9. POSTMTC.SET	*Queueing post-processor for the MINUTP assignment**

**Optional program for refinement of travel speeds from base MINUTP assignment*

To install the AIRQ software simply copy the contents of the distribution diskette into a specified directory (e.g., C:\AIRQ) in the microcomputer's hard disk. The files may also be copied to an existing directory used for MINUTP network analysis.

FIGURE B.1 THE AIRQ SOFTWARE



B.3 Run AIRQMTC.SET to Process MINUTP Output

AIRQMTC.SET is a MINUTP command file written using the commands of the NETMRG data manipulation routine to create the link file required by the AIRQ software. The listing of the file is included in Appendix D.

The program is run **following the execution of the MINUTP assignment** using the standard commands of the MINUTP software to execute .SET files. For example, type MINUTP to invoke the main setup and specify AIRQMTC.SET as input:

```
                         COMSIS MINUTP

File Control:                                 Parameters:

 MINUTP DRV E (a-z)                            Zones 1120

 INPUT  AIRQMTC.SET                            Nodes 15002

 OUTPUT DSK (con,dsk,prn)                      Error Level 7

 Data File Prefix LOAD (must be 4 chars)       Beginning Page no.   1

 ID PROCESSING MTC NETWORK ASSIGNMENT          Lines/Page    66
------------------------------------------------------------------------
```

Note:

Users may run the queueing post-processor (POSTMTC.SET) to improve the estimates of travel speeds before processing the MINUTP output. Instructions for running the POSTMTC.SET file are given in Section B.7.

The output file from the MINUTP assignment and the AIRQMTC.SET file must reside in the same directory, and the directory with the MINUTP programs in included in the PATH statement in the autoexec.bat file. Otherwise, both the loaded network file and the program should be in the same directory as the MINUTP program files.

The program processes the information from the loaded network to calculate link capacity, VMT, VHT and link type (ID) and produces an ASCII formatted text file with the following fields in each record:

Anode, Bnode, Distance, Free Speed, Capacity, Facility type, Area type, Volume, Avg Speed, v/c, Link ID, VMT, VHT

The user may specify the name of the file in the following statement of the AIRQMTC.SET file:

LSTO 2, filename *DEFAULT: AIRQINP.INP*

A sample link data file created by the program is shown below:

```
1201 1225   33   30  65043  507  296   78 6        16731    33969
1202 1230   30   65 390024 1634  643   42 2        49020    45752
1209 1208    6   65 390024 2458  600   63 2        14748    14748
121411082   58   65 390024 2020  644   52 2       117160   109080
1215 1218   57   65 390024 2591  645   66 2       147687   137323
121611116   35   65 390024 1867  656   48 2        65345    59744
1217 1241   93   40 190074  587  399   3111        54591    82180
1231 1232   40   65 390025 3250  632   83 2       130000   123500
1232 1233  206   65 390024 3250  631   83 2       669500   637000
1240 2181   57   65 585024 7403  207  127 2       421971  1221495
124111105   81   40 190074  777  398   4111        62937    94794
124111118   21   40  95074  865  360   9111        18165    30275
1242 1291    5   65 585024 2018  600   34 2        10090    10090
1246 1245   42   65 390024 2454  646   63 2       103068    95706
1249 1273   43   65 585024 7403  208  127 2       318329   917972
1250 1249   31   40 140054 1341  351   96 8        41571    71073
```

Program Options and Controls

1. Select Links for Processing

The default selection of the network links for processing includes all the links except centroid/connector links. The user could select other criteria for link processing through the NETMRG IF, USE, SKIP statements in the program. This allows the process only certain facility types, OR portions of the network (an urban county). For example, the following commands can be used to process arterial links with volumes:

USE FT=7	*Process only arterial links*
IF VOL=1-99999	*Process only links with volumes*
ENDIF	*for VOL=1-99999*

2. Coding of Link free-flow speed and type (ID)

The link free-flow speed (FFS) is coded based on the values in the speed/capacity tables for facility and area types in the 1990 MTC network. This is illustrated below for the freeway links:

@ FT=2,AT=0-1 FFS=55
@ FT=2,AT=2-3 FFS=60
@ FT=2,AT=4-5 FFS=65

Any future revisions to the tables would involve changing the values of free-flow speeds coded in the program. Also, these statements should be commented-out (by plasing the $ sign in front of each statement) if the free-flow speeds are explicitly coded for the network links.

The link types (ID) are determined based on the facility/area type designations based on the procedures described in Chapter 4 of the report taking into consideration the link information coded in the MTC network. The determination of the link ID is illustrated below for the arterials in the 1120 zone MTC network:

@ FT=7,AT=0-1	*ID=9*	*Core/CBD arterial links*
@ FT=7,AT=2-3	*ID=10*	*UBD/Urban arterial links*
@ FT=7,AT=4	*ID=11*	*Suburban arterial links*
@ FT=7,AT=5	*ID=4*	*Rural arterial links*

The correspondence between the link IDs and the MTC link designations is shown in the following table:

TABLE B.2 RELATION BETWEEN MTC LINK DESIGNATIONS AND LINK ID

AREA TYPE	**FACILITY TYPE**							
	Fwy-to-Fwy (1)	Fwy (2)	Expwy (3)	Collector (4)	Ramp (5)	Dummy (6)	Major Art (7)	Metered Ramp (8)
Core (0)	1 (1)	2 (2)	3 (3)	4 (5)	5 (7)		6 (9)	7 (12)
CBD(1)	1 (1)	2 (2)	3 (3)	8 (5)	5 (7)		9 (9)	7 (12)
UBD (2)	10 (1)	11 (2)	12 (4)	13 (6)	14 (8)		15 (10)	16 (12)
Urban (3)	10 (1)	11 (2)	12 (4)	13 (6)	14 (8)		15 (10)	16 (12)
Suburban (4)	17 (2)	18 (2)	19 (4)	20 (6)	21 (8)		22 (11)	23 (12)
Rural (5)	17 (2)	18 (2)	24 (4)	25 (6)	21 (8)		26 (4)	23 (12)

Definition of cell xx (yy) entries
xx: Link type based on MTC different entries of speed/capacity per facility/area type
yy: Equivalent Link ID for the AIRQ model

If the "link type" variable has been coded in the network based on the proposed link type scheme shown in Table 3.3, then these statements should be commented out in the AIRQMTC.SET file.

B.4 Running the AIRQ Program

B.4.1 Interactive Mode

Users enter AIRQ at the DOS prompt and hit <RETURN>. The following menu appears on the screen:

```
*****************************************************
*          A-I-R-Q    POST-PROCESSOR                *
*   ESTIMATION OF TIME-SPENT PER DRIVING MODE       *
* FROM THE OUTPUT OF "FOUR-STEP" REGIONAL MODELS    *
*---------------------------------------------------*
*                                                   *
*     1. Run the Program                            *
*     2. View Network Statistics                    *
*     3. View Link Summary Performance              *
*     4. View Link Specific Vehicle-Activity        *
*     5. Exit                                       *
*                                                   *
*****************************************************


  Enter Menu Choice
```

A. Option 1 (Run Program):

The program asks to enter the name of the input file. This is the link characteristics file created with the AIRQMTC.SET program. Next, the user is prompted to enter the names of the output files (and hit <RETURN>) as shown below:

```
Enter Menu Choice  1

Enter Input File Name:  mtc90.inp

Network Statistics
   Enter Output File  mtcn90.out

Do you want Link Performance Summary Output (y/n) y

    Enter Output File  mtcl90.out

Do you want Link Specific Veh-Activity Output (y/n) n
```

The program checks if the entered filenames exist and prompts the user with the options to re-enter the filenames, overwrite existing output files or quit the program. Following the AIRQ program execution, the following output files are produced:

Network Statistics output: This output file is always generated by the program and consists of the following four parts:

(1) Vehicle-activity (veh-hr) by speed-acceleration category for each facility type. (Figure B.2).

(2) Vehicle-activity (veh-hr) by speed-acceleration category for the total network. (Figure B.3).

(3) Network summary statistics including VMT (veh-mi), VHT (veh-hr), DELAY (Veh-hr) and average travel speed (Figure B.3).

(4) Total time spent in cruise, acceleration, deceleration and idle driving modes for the entire network by facility type and area type (Figure B.4).

Link Performance Summary Output (Optional): This output is generated at the user's request and provides information on the basic link characteristics, traffic performance (speed, v/c, VMT, VHT, VHD), and the total time spent in each driving mode (Figure B.5).

Link Specific Vehicle Activity Output (Optional): This output is also generated at the user's request and provides the vehicle-activity (veh-min) for each link by speed-acceleration category (Figure B.6). The output also includes the link identification (Anode, Bnode), facility and area type and the total veh-hr of travel. This output option generates large files especially for big networks and it is suited for verification runs. For example, about 14 MB of hard disk storage would be needed for the 22,000 non-centroid links in the MTC 1120 zone network.

B. Options 2/3/4 (Viewing the Outputs)

These options allow the user to view each output file on the screen **after** a program run was made. The viewing of the files is done through the LIST utility program which is included in the utilities distributed with the MINUTP software and other transportation software packages. The LIST program allows for searching for specific information in the output, and printing of portions of, or the entire output file.

If an output file has not been requested during the program execution, the program prints out a message that the output was not requested and returns to the main menu.

C. Option 5 (Exit)

This option simply terminates the execution of the AIRQ program.

B.4.2 Offline (Batch) Mode

The AIRQ program can be executed in offline batch mode. This is the preferred approach for processing large networks and performing multiple runs. It also allows the AIRQ software to be part of the MINUTP software setup for the analysis of the network, so users can get the results from both the traffic assignment and the vehicle activity in a single computer run.

A. Create the Run File

First, the user has to specify the input and output files in a run file called **AIRQ.FIL**. The contents of this file (which is provided in the distribution disk) are shown below:

CONTENTS OF THE AIRQ.FIL Run File

Input Data File:	AIRQINP.INP
Output Level Flag:	0
Network Statistics:	TABLE1.OUT
Link Summaries:	TABLE2.OUT
Link Veh Activity:	TABLE3.OUT

Users specify the input and output file names by editing the AIRQ.FIL. The output level flag is coded as follows:

0 Network Statistics output only
1 Add Link Summary Performance output
2 Add Link Specific Veh-Activity output

If the output level flag is coded as zero, it is not necessary to delete the filenames for the non-requested output files in the AIRQ.FIL run file. The program simply ignores those filenames.

B. Run the Program

To execute the run the program simply enter **AIRQO** at the DOS prompt and press <RETURN>. The output files can be viewed with the LIST utility program and can be printed with the DOS PRINT command or from within the LIST program.

C. Notes

(1) Note that if the output files specified already exist they will be overwritten by the program.

(2) The run file name should always be AIRQ.FIL and be in the same directory as the AIRQ software.

B.5 Example 1: Multiple AIRQ Program Runs

This example describes how the AIRQ software can be used to generate vehicle activity data from multiple MINUTP outputs, e.g., network assignments for the am, midday and pm peak periods of a network. The following steps are undertaken:

(1) Run the AIRQMTC.SET command file following the execution of each MINUTP run. This would create the following link data files for the AIRQ Program:

AMPEAK.INP	*am peak link data file*
MIDDAY.INP	*midday link data file*
PMPEAK.INP	*pm peak link data file*

(2) Create three run files each for each period analyzed in Step (1) above:

	AMPEAK.FIL	**MIDDAY.FIL**	**PMPEAK.FIL**
Input Data File:	AMPEAK.INP	MIDDAY.INP	PMPEAK.INP
Output Level Flag:	0	0	0
Network Statistics:	AMPEAK1.OUT	MIDDAY1.OUT	PMPEAK1.OUT
Link Summaries:	AMPEAK2.OUT	MIDDAY2.OUT	PMPEAK2.OUT
Link Veh Activity:	AMPEAK3.OUT	MIDDAY3.OUT	PMPEAK3.OUT

(3) Use the following setup in a DOS batch file to perform the runs and get the results on time-spent for all time periods:

```
@ECHO=OFF
REM  FILE:MAIRQ.BAT
REM  Batch File for Multiple AIRQ Program Runs
REM--
COPY AMPEAK.FIL AIRQ.FIL
AIRQO
COPY MIDDAY.FIL AIRQ.FIL
AIRQO
COPY PMPEAK.FIL AIRQ.FIL
AIRQO
REM--
COPY *1.OUT  NETWORK.OUT
ERASE *1.OUT
ECHO=ON
```

B.6 Example 2: Combined MINUTP and AIRQ Models Run

The MINUTP analysis and vehicle activity estimation for a network can be accomplished in a single computer run using the following setup in a DOS batch file:

```
@ECHO=OFF
REM  FILE:MIN_ARQ.BAT
REM  Batch File for Combined MINUTP and AIRQ Models Run
REM--
MUTP1.BAT
MUTP2.BAT
AIRQO
ECHO=ON
```

where:

MUTP1.BAT: This is the DOS batch file created by MINUTP to process the traffic assignment.

MUTP2.BAT: This is a similar DOS batch file created by MINUTP to process the AIRQMTC.SET module of the AIRQ software.

AIRQO: The executable file of the AIRQ program for batch runs

The file specifications for this run are:

LOADXXX.NET: This is the binary loaded network file from the MINUTP assignment (end of processing of the MUTP1.BAT). This file is called LOAD27.NET for the MTC network.

This file should be specified in the AIRQMTC.SET file for processing of the link data as described in Section B.3 (page B-4)

AIRQINP.INP: This is the link data file output from the AIRQMTC.SET run under the MUTP2.BAT file. Users may select a different name as described in Section B.3 (page B-4)

AIRQ.FIL: This is the run file for the AIRQO software. The input file specified should be the same as the one produced by the AIRQMTC.SET (e.g., AIRQINP.INP in this example.)

FIGURE B.2 NETWORK VEHICLE ACTIVITY OUTPUT FROM THE AIRQ PROGRAM BY FACILITY TYPE

VEHICLE ACTIVITY FOR FACILITY TYPE: 2
TIME-SPENT (Veh-hr) BY SPEED(mph) and ACCELERATION(mph/sec)

"MPH"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	TOTAL
0	.0	.0	.0	.0	.0	.0	.0	3226.0	.0	.0	.0	.0	.0	.0	.0	3226.0
5	.0	.0	47.3	47.3	47.3	468.1	1226.2	1492.6	1320.8	320.0	94.5	47.3	.0	.0	.0	5111.3
10	.0	.0	47.3	47.3	107.3	356.3	794.5	1185.3	949.0	296.3	47.3	47.3	.0	.0	.0	3877.7
15	.0	.0	47.3	107.3	107.3	356.3	949.0	1399.8	1103.5	450.9	107.3	47.3	.0	.0	.0	4675.8
20	.0	.0	.0	107.3	107.3	309.0	1009.0	1318.0	1150.8	403.6	107.3	.0	.0	.0	.0	4512.1
25	.0	.0	.0	107.3	107.3	356.3	1056.2	1425.3	1352.6	403.6	47.3	.0	.0	.0	.0	4855.7
30	.0	.0	47.3	107.3	107.3	309.0	1163.5	1532.5	1412.5	450.9	.0	.0	.0	.0	.0	5130.2
35	.0	.0	.0	107.3	154.5	214.5	892.6	1227.1	1283.4	309.0	47.3	.0	.0	.0	.0	4235.7
40	.0	.0	.0	47.3	60.0	214.5	1072.5	1227.1	1356.1	309.0	.0	.0	.0	.0	.0	4286.5
45	.0	.0	.0	107.3	60.0	214.5	1072.5	1570.7	1274.3	154.5	.0	.0	.0	.0	.0	4453.8
50	.0	.0	.0	60.0	60.0	167.2	2183.2	4539.2	2230.5	167.2	.0	.0	47.3	.0	.0	9454.6
55	.0	47.3	107.3	107.3	60.0	227.2	5498.9	13060.8	5357.1	274.5	.0	.0	.0	.0	.0	24740.4
60	.0	.0	.0	.0	.0	120.0	3991.9	12055.5	4695.4	274.5	154.5	47.3	.0	.0	.0	21339.0
65	.0	.0	.0	.0	.0	60.0	1187.0	4251.7	1641.4	107.3	107.3	.0	.0	.0	.0	7354.6
TOTAL	.0	47.3	296.3	952.6	978.0	3373.1	22096.9	49511.5	25127.4	3921.3	712.6	189.1	47.3	.0	.0	107253.3

VEHICLE ACTIVITY FOR FACILITY TYPE: 7
TIME-SPENT (Veh-hr) BY SPEED(mph) and ACCELERATION(mph/sec)

"MPH"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	TOTAL
0	.0	.0	.0	.0	.0	.0	.0	29450.3	.0	.0	.0	.0	.0	.0	.0	29450.3
5	.0	.0	171.4	14.5	14.2	967.1	528.1	5929.7	306.8	151.5	277.1	102.9	695.2	19.1	.0	9177.7
10	.0	.0	62.2	77.0	276.6	766.1	447.4	851.2	512.7	252.1	421.9	548.7	266.3	116.5	.0	4598.6
15	.0	.0	86.9	315.8	270.3	609.3	348.6	612.1	351.7	115.1	744.1	578.0	140.9	157.2	.0	4330.0
20	.0	.0	118.3	434.0	213.9	691.4	412.6	721.1	554.4	421.5	1905.2	105.0	34.8	110.3	.0	5722.5
25	.0	.0	104.6	332.3	161.3	616.2	360.5	1169.4	1804.2	1236.7	941.4	10.2	1.5	28.2	.0	6766.4
30	.0	.0	64.7	290.6	154.6	436.0	651.5	8168.6	6189.0	1122.4	185.0	1.8	.0	10.2	.0	17274.4
35	.0	.0	47.7	121.4	87.5	375.2	512.4	6387.7	5519.8	279.6	35.3	.0	.0	.0	.0	13366.6
40	.0	.0	16.8	27.7	24.8	95.9	166.9	2290.0	2029.4	45.0	2.6	.0	.0	.0	.0	4699.2
45	.0	.0	5.0	7.4	6.2	37.9	63.6	1044.1	656.8	11.6	.6	.0	.0	.0	.0	1833.2
50	.0	.0	3.2	4.4	2.4	12.7	30.5	853.5	441.1	.0	.0	.0	.0	.0	.0	1347.9
55	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
65	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	.0	.0	681.0	1625.0	1211.9	4607.7	3522.2	57477.7	18365.9	3635.5	4513.2	1346.5	1138.7	441.5	.0	98567.0

FIGURE B.3 NETWORK VEHICLE ACTIVITY OUTPUT FROM THE AIRQ PROGRAM

VEHICLE ACTIVITY FOR THE TOTAL NETWORK
TIME-SPENT (Veh-hr) BY SPEED(mph) and ACCELERATION(mph/sec)

"MPH"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	TOTAL
0	.0	.0	.0	.0	.0	.0	.0	54268.2	.0	.0	.0	.0	.0	.0	.0	54268.2
5	.0	.0	398.0	100.7	94.1	2257.4	2434.2	11882.9	2233.4	756.1	621.7	263.9	1230.4	38.8	.0	22311.8
10	.0	.0	146.5	194.1	627.0	1755.6	1708.0	2742.9	2073.5	793.5	823.7	1130.6	482.4	201.4	.0	12679.1
15	.0	.0	188.6	710.5	610.6	1444.1	1713.3	2547.2	1919.6	689.4	1569.1	978.0	231.5	268.9	.0	12870.9
20	.0	.0	209.3	929.5	539.8	1568.8	1877.6	2594.8	2430.1	1328.8	3393.3	182.9	69.5	183.5	.0	15307.9
25	.0	.0	164.4	684.6	382.5	1429.0	1997.9	5163.5	5625.5	2542.0	1457.4	22.1	18.6	50.5	.0	19538.1
30	.0	12.2	173.7	583.4	365.1	995.5	2818.5	13992.3	11068.9	2167.8	299.1	1.8	.0	16.7	.0	32495.1
35	.0	.0	78.2	303.9	293.7	747.0	2134.1	10407.8	8996.2	762.5	142.8	12.2	.0	.0	.0	23878.3
40	.0	.0	30.7	92.2	97.9	362.4	1708.5	6004.5	4928.3	438.4	23.0	.0	.0	.0	.0	13685.8
45	.0	.0	9.0	120.9	69.7	293.4	1389.7	4087.9	2746.6	192.0	7.9	.0	.0	.0	.0	8917.1
50	.0	.0	7.2	68.0	63.6	196.6	2300.0	6536.0	3230.9	170.4	1.4	.0	48.2	.0	.0	12622.3
55	.0	48.2	108.6	108.6	60.4	229.4	5564.5	13195.8	5419.8	277.6	.0	.0	.0	.0	.0	25013.0
60	.0	.0	.0	.0	.0	120.8	4032.5	12170.8	4744.6	277.6	156.9	48.2	.0	.0	.0	21551.4
65	.0	.0	.0	.0	.0	60.4	1195.7	4287.1	1654.5	108.6	108.6	.0	.0	.0	.0	7414.9
TOTAL	.0	60.4	1514.1	3896.4	3204.6	11460.6	30874.4	149881.7	57072.0	10504.8	8604.9	2639.6	2080.6	759.9	.0	282554.1

NETWORK SUMMARY STATISTICS

NETWORK SUMMARY STATISTICS	
TOTAL DISTANCE TRAVELED (VMT):	8814993.0
TOTAL TRAVEL TIME (VHT):	282552.0
TOTAL DELAY (VHD):	100137.9
AVERAGE NETWORK SPEED (MPH):	31.2

FIGURE B.4 NETWORK SUMMARY BY VEHICLE TYPE AND FACILITY TYPE

SUMMARY STATISTICS FOR THE NETWORK

TOTAL TIME-SPENT IN CRUISE MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	61.31	.00	104.43	37.36	.00	486.63	.00	689.73
CBD	8.32	372.98	31.72	259.29	293.24	.00	1334.51	.00	2300.06
UBD	293.26	5162.74	1637.43	1076.36	636.96	.00	5083.31	.00	13890.05
URBAN	681.99	16253.20	1093.96	3618.56	1437.94	.00	9395.71	.00	32481.36
SUBURBAN	220.65	17654.44	985.65	3159.34	2511.77	.00	8527.00	.00	33058.86
RURAL	26.41	6780.73	288.56	2785.75	111.71	.00	3200.28	.00	13193.45
TOTAL	1230.64	46285.41	4037.32	11003.73	5028.98	.00	28027.43	.00	95613.52

TOTAL TIME-SPENT IN ACCELERATION MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	30.60	.00	77.66	22.88	.00	470.56	.00	601.70
CBD	3.94	246.74	48.63	328.74	246.13	.00	1350.80	.00	2224.98
UBD	170.68	3237.97	1622.97	1305.01	352.45	.00	5121.34	.00	11810.43
URBAN	421.03	11681.64	1018.70	5274.57	989.15	.00	9289.05	.00	28674.14
SUBURBAN	127.69	11118.34	840.48	3933.57	2066.75	.00	10284.88	.00	28371.72
RURAL	13.14	3682.32	247.54	3057.16	54.01	.00	2924.72	.00	9978.89
TOTAL	736.49	29997.62	3778.32	13976.70	3731.37	.00	29441.36	.00	81661.85

TOTAL TIME-SPENT IN DECELERATION MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	30.29	.00	34.42	20.57	.00	208.44	.00	293.72
CBD	3.87	227.12	20.34	150.76	209.70	.00	612.57	.00	1224.36
UBD	159.53	3018.16	553.69	602.41	328.33	.00	2054.28	.00	6716.41
URBAN	388.62	10550.13	335.31	2475.73	878.78	.00	3664.00	.00	18292.56
SUBURBAN	121.37	10355.52	255.55	1791.45	1776.27	.00	4169.42	.00	18469.58
RURAL	13.01	3562.96	68.02	1378.83	52.01	.00	939.04	.00	6013.88
TOTAL	686.40	27744.18	1232.92	6433.60	3265.67	.00	11647.74	.00	51010.50

TOTAL TIME-SPENT IN IDLE MODE (Veh-h)

AREA TYPE	FACILITY TYPE 1	2	3	4	5	6	7	8	TOTAL
CORE	.00	.44	.00	17.74	2.09	.00	250.83	.00	271.10
CBD	.05	28.16	64.87	410.13	34.75	.00	1209.30	.00	1747.26
UBD	14.48	313.85	1481.32	1699.61	21.37	.00	5728.58	.00	9259.22
URBAN	43.08	1593.62	796.46	8828.22	105.02	.00	9764.55	.00	21130.95
SUBURBAN	8.58	1105.19	458.24	4477.51	284.74	.00	10399.65	.00	16733.93
RURAL	.11	184.75	96.92	2745.25	1.31	.00	2097.40	.00	5125.73
TOTAL	66.30	3226.01	2897.81	18178.47	449.29	.00	29450.31	.00	54268.19

FIGURE B.5 LINK SUMMARY OUTPUT FROM THE AIRQ PROGRAM

LINK CHARACTERISTICS						LINK PERFORMANCE						VEHICLE ACTIVITY			
LINK	DIST	SP	CAPA	F	A	VOL	CSP	VC	VMT	VHT	VHD	CRUI	ACC	DEC	IDLE
1201 1225	.33	30	650	4	3	507	29.6	78	167.31	5.66	.08	1.23	1.92	.85	1.67
1202 1230	.30	65	3900	2	4	1634	64.3	42	490.20	7.63	.08	3.79	1.90	1.88	.05
1209 1208	.06	65	3900	2	4	2458	60.0	63	147.48	2.46	.19	1.22	.61	.61	.02
121411082	.58	65	3900	2	4	2020	64.4	52	1171.60	18.18	.16	9.04	4.54	4.49	.12
1215 1218	.57	65	3900	2	4	2591	64.5	66	1476.87	22.89	.17	11.37	5.71	5.65	.15
121611116	.35	65	3900	2	4	1867	65.0	48	653.45	9.96	.00	5.01	2.48	2.46	.00
1217 1241	.93	40	1900	7	4	587	39.9	31	545.91	13.70	.05	4.10	5.02	1.82	2.75
1231 1232	.40	65	3900	2	5	3250	63.2	83	1300.00	20.58	.58	10.23	5.14	5.08	.13
1232 1233	2.06	65	3900	2	4	3250	63.1	83	6695.00	106.17	3.17	52.76	26.49	26.22	.69
1240 2181	.57	65	5850	2	4	7403	20.7	127	4219.71	203.58	138.66	70.44	64.74	55.68	12.72
124111105	.81	40	1900	7	4	777	39.8	41	629.37	15.80	.06	4.73	5.80	2.10	3.17
124111118	.21	40	950	7	4	865	36.0	91	181.65	5.05	.50	1.51	1.85	.67	1.01
1242 1291	.05	65	5850	2	4	2018	60.0	34	100.90	1.68	.13	.84	.42	.42	.01
1246 1245	.42	65	3900	2	4	2454	64.6	63	1030.68	15.95	.09	7.93	3.98	3.94	.10
1249 1273	.43	65	5850	2	4	7403	20.8	127	3183.29	153.00	104.02	52.94	48.65	41.84	9.56
1250 1249	.31	40	1400	5	4	1341	35.1	96	415.71	11.85	1.45	6.12	2.86	2.78	.08

FIGURE B.6 LINK VEHICLE-ACTIVITY OUTPUT FROM THE AIRQ PROGRAM

LINK#: 1202 1230 FACILITY TYPE: 2 AREA TYPE: 4 VHT(Veh-hr): 7.63

TIME-SPENT(Veh-min) BY SPEED(mph) and ACCELERATION(mph/sec)

"MPH"	-7	-6	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	+6	+7	TOTAL
0	.0	.0	.0	.0	.0	.0	.0	3.0	.0	.0	.0	.0	.0	.0	.0	3.0
5	.0	.0	.0	.0	.0	.7	1.6	1.8	1.6	.5	.0	.0	.0	.0	.0	6.2
10	.0	.0	.0	.0	.5	.9	1.4	1.8	1.8	.5	.0	.0	.0	.0	.0	6.9
15	.0	.0	.0	.5	.5	.9	1.8	2.7	2.3	.9	.5	.0	.0	.0	.0	10.1
20	.0	.0	.0	.5	.5	.9	2.3	3.2	2.3	.9	.5	.0	.0	.0	.0	11.0
25	.0	.0	.0	.5	.5	.9	2.3	3.7	2.7	.9	.0	.0	.0	.0	.0	11.4
30	.0	.0	.0	.5	.5	.9	2.7	4.1	3.2	.9	.0	.0	.0	.0	.0	12.8
35	.0	.0	.0	.5	.5	.9	3.2	5.0	3.7	.9	.0	.0	.0	.0	.0	14.6
40	.0	.0	.0	.0	.5	.9	4.6	5.0	4.6	.9	.0	.0	.0	.0	.0	16.5
45	.0	.0	.0	.5	.5	.9	4.6	5.5	5.0	.5	.0	.0	.0	.0	.0	17.4
50	.0	.0	.0	.5	.5	.9	10.5	18.8	10.5	.9	.0	.0	.0	.0	.0	42.5
55	.0	.0	.5	.5	.5	1.4	26.1	73.7	26.1	1.4	.0	.0	.0	.0	.0	129.9
60	.0	.0	.0	.0	.0	.9	22.9	73.2	26.1	1.4	.5	.0	.0	.0	.0	124.9
65	.0	.0	.0	.0	.0	.5	8.7	28.8	11.4	.5	.5	.0	.0	.0	.0	50.3
TOTAL	.0	.0	.5	3.7	4.6	11.7	92.6	230.4	101.3	11.0	1.8	.0	.0	.0	.0	457.5

B.7 Running the POSTMTC Queueing Post-Processor as part of the AIRQ software

The POSTMTC.SET queueing post-processor is a MINUTP command file written using the commands of the NETMRG data manipulation routine to improve the average travel speed estimates from the MINUTP assignment module. POSTSMTC adjusts the link speeds using a queueing model for the congested links. The program outputs include average speeds and other performance measures, and tabulations of VMT, and VHT per each speed range 0-70 mph. The basic computational steps are described in Section 5.2B of the report, and the listing of the file is included in Appendix F.

It is not required to run POSTMTC.SET to obtain network vehicle activity estimates with the AIRQ software. A number of applications, however, indicate that the program improves the accuracy of the MINUTP predicted link speeds and veh-hours of travel, which are basic inputs to the AIRQ software.

A. Run the POSTMTC.SET Program

The program is run **following the execution of the MINUTP assignment and running the AIRQMTC file to process the output (Figure B.1).** The program runs using standard commands of the MINUTP software to execute .SET files. User required (or optional) controls include:

1. Specify the Input/Output Networks

Specify the input/output networks to be processed. The input network to be processed by POSTMTC.SET is the loaded network from the MINUTP assignment in binary format. The output network, also in binary format, is the one produced by POSTMTC and includes the improved speed estimates.

```
*PGM NETMRG LOADPS.NET LOAD27.NET
NET 0=LOADPS.NET,1=LOAD27.NET
```

where: LOAD27.NET the input filename (network with assigned volumes/speeds)
LOADPS.NET the output network from the post-processor

2. Select Links for Processing

This is the same step as described for the AIRQMTC.SET file. The default selection of the network links for processing includes all the links with volumes except centroid/connector links:

```
SKIP FT=6          Exclude dummy links
IF VOL=1-99999       Process only links with volumes
ENDIF             for VOL=1-99999
```

3. **Coding of Link free-flow speed**

The link free-flow speed (FFS) is coded based on the values in the speed/capacity tables for facility and area types in the 1990 MTC network, as described in section B.1 for the AIRQMTC.SET program.

4. **Set Parameters for the Speed-Flow Curve**

The post-processor allows the user specify the parameters of the BPR type speed-flow curve used to calculate the speeds on uncongested links. The default values correspond to the values used in the 1990 MTC 1120 zone network:

COMP CFA=20	*"alpha" coefficient * 100*
COMP BETA=10	*"beta" exponent*
COMP KAP=100	*K factor * 100*

5. **Determine Peak Period Flows**

The post-processor models the peak period into six 1 hr time slices, e.g., 5:00-11:00 am. The hourly volumes flow rates for peak hour are determined as a percentage of the peak hour flow, based on available empirical data. Users can override the default values in the post-processor to more accurately match observed travel patterns:

$ COMPUTE HOURLY VOLUMES	*---------5-6 am-------*
*COMP HRVOL=VOL*0.142*	*14 % of the peak hour volume*

B. Run the AIRQ Software

Following the execution of the POSTMTC.SET post-processor, the AIRQ software may run to obtain vehicle activity estimates as described in the previous sections. The only change required is that in the **AIRQMTC.SET** file, the new network must be specified:

```
*PGM NETMRG LOAD28.NET LOADPS.NET
NET 0=NUL,1=LOADPS.NET
```

where: LOADPS.NET the input filename (output network from the POSTMTC.SET run)

The instructions and examples on the AIRQ software described in the previous sections also apply for the combination of POSTMTC and AIRQ programs.

APPENDIX C. COMPARISON OF MTC MODEL PREDICTIONS WITH FIELD DATA

prepared by:

Ann Stevens
Ann Stevens Associates

TABLE C.1 TRAFFIC VOLUMES ON SELECTED FREEWAY LINKS: OBSERVED .vs MTC 1990 ASSIGNMENT

A Node	B Node	Through Street	A Node Street	B Node Street	Observed	MTC 1990 Assigned
2224	2210	I-80 East Bound	Highway 4 Off-Ramp	Willow On-Ramp	3572	2532
2290	2291	I-80 East Bound	Appian Way Off-Ramp	Pinole Valley On-Ramp	3228	3390
2261	2265	I-80 East Bound	San Pablo Dam Rd. Off-Ramp	El Portal On-Ramp	3297	3184
2420	2422	I-80 East Bound	Central Off-Ramp	Carlson On-Ramp	5407	3503
2634	2636	I-80 East Bound	Powell Off-Ramp	Ashby On-Ramp	6309	6718
2211	2221	I-80 West Bound	Willow Off-Ramp	Highway 4 On-Ramp	5658	6247
2216	2215	I-80 West Bound	Pinole Valley Off-Ramp	Appian Way On-Ramp	4763	7809
2256	2260	I-80 West Bound	El Portal Off-Ramp	San Pablo Dam Rd. On-Ramp	5266	5360
2637	2633	I-80 West Bound	Ashby Off-Ramp	Powell On-Ramp	7804	8642
3360	3361	I-880 Northbound	Marina	Davis	8330	7064
3363	3365	I-880 Northbound	Davis	98th Ave.	8480	7068
3291	3293	I-880 Northbound	98th Ave.	Hegenberger	8330	6521
3297	2663	I-880 Northbound	Hegenberger	66th Ave.	7940	6102
2664	3315	I-880 Northbound	66th Ave.	High St.	8330	6582
3315	3190	I-880 Northbound	High St	29th/Fruitvale	8510	5464
3190	3183	I-880 Northbound	29th/Fruitvale	23rd Ave.	8260	6764
3188	2684	I-880 Northbound	23rd	Embarcadero/5th	8190	6732
5103	5085	I-880 Northbound	82/The Alameda	Coleman	6355	6383
5142	5105	I-880 Northbound	Bascom	82/The Alameda	6966	5685
5145	5144	I-880 Northbound	Stevens Creek	Bascom	6888	7100
2737	2738	I-880 South Bound	Embarcadero/5th	23rd	6610	3819
3184	3191	I-880 South Bound	23rd Ave.	29th/Fruitvale	6670	4145
3191	3316	I-880 South Bound	29th/Fruitvale	High St.	6870	3731
3316	2665	I-880 South Bound	High St.	66th Ave.	6730	5022
2682	3296	I-880 South Bound	66th Ave.	Hegenberger	6410	5111
3294	3292	I-880 South Bound	Hegenberger	98th Ave.	6730	4906
3289	3281	I-880 South Bound	98th Ave.	Davis	6840	4923
3279	3278	I-880 South Bound	Davis	Marina	6980	5064
5689	5691	I-880 South Bound	Old Bayshore/Gish	Hwy 101	3154	4128
5271	5272	I-880 South Bound	Hwy 101	First St North	3078	5348
5276	5292	I-880 South Bound	Coleman	82/The Alameda	2601	4775
5294	5122	I-880 South Bound	82/The Alameda	Bascom	2612	4124
3480	3447	I-580 Westbound	Fairmont/Plaza	150th Ave.	5980	5576
3447	3453	I-580 Westbound	150th Ave.	Benedict	6238	7089
3480	3477	I-580 Westbound	Benedict	Grand (San Leandro)	6790	7089
3477	3456	I-580 Westbound	Grand (San Leandro)	Estudillo	6010	7089
3062	3061	I-580 Westbound	Estudillo	Foothill/MacArthur	5670	7123
		I-580 Westbound	Foothill/MacArthur	106th Ave.	5880	6804
3354	3351	I-580 Westbound	106th Ave.	98th/Golf Links	5760	6804
3068	3066	I-580 Westbound	98th/Golf Links	Keller/Mountain	6280	6882
3086	3055	I-580 Westbound	Keller/Mountain	Edwards	6545	7399
3055	3054	I-580 Westbound	Edwards	13/Seminary/Warren	6545	7505
3054	3126	I-580 Westbound	13/Seminary/Warren	MacArthur	5796	4716
3132	3116	I-580 Westbound	MacArthur	High	5930	5153
3116	3144	I-580 Westbound	High	35th	6230	5543
3144	2958	I-580 Westbound	35th	Fruitvale	7180	5859
2958	2959	I-580 Westbound	Fruitvale	14th Ave.	7470	7345
2963	2964	I-580 Westbound	Park	Lakeshore/Grand	6730	7983
2902	2911	I-580 Westbound	Lakeshore/Grand	Harrison/Oakland	7940	7426
2906	2708	I-580 Westbound	Harrison/Oakland	24/980	7800	6639
2711	2772	I-580 Westbound	24/980	San Pablo	6910	8184
2772	2773	I-580 Westbound	San Pablo	MacArthur Maze	8070	9721
2634	2636	I-580 Westbound	Powell (Emryville)	Ashby	6309	6718
2247	3342	I-580 Westbound	Toll Plaza Richmond-SR	1st Incline, SR Bridge	2360	3383

TABLE C.1 (Cont.)

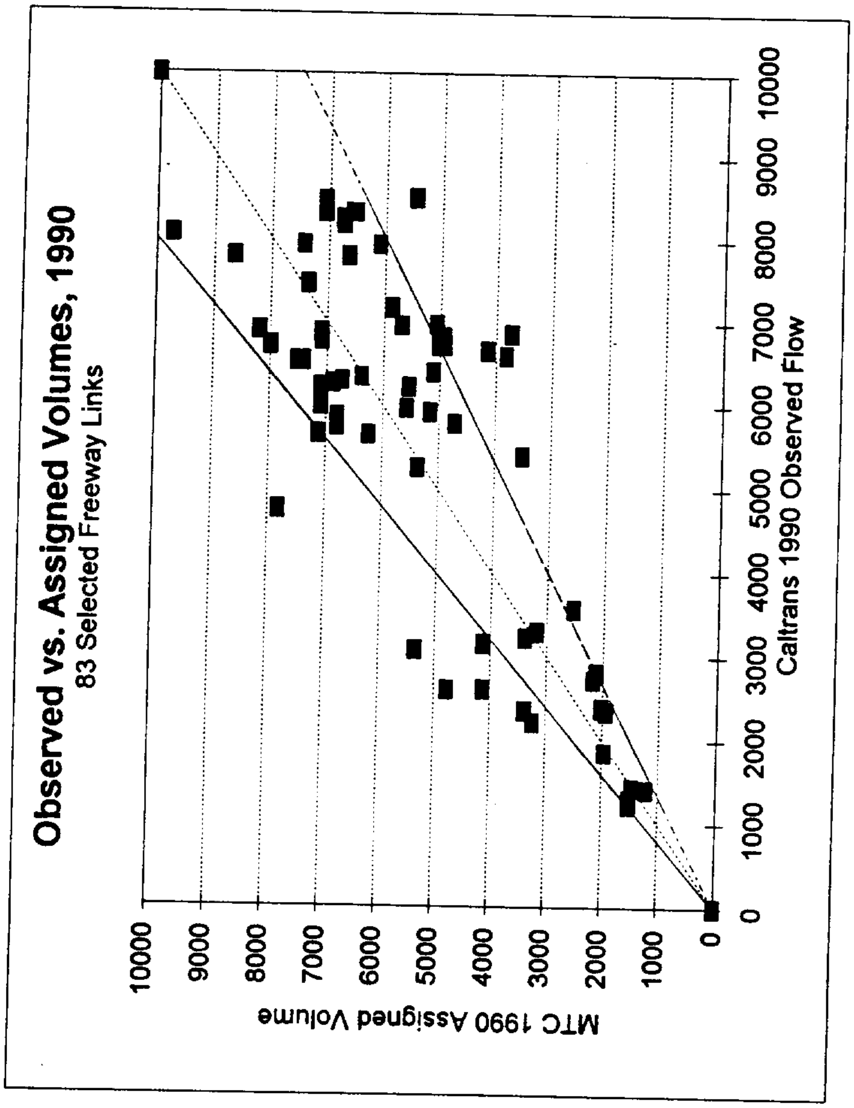
A Node	B Node	Through Street	A Node Street	B Node Street	Observed*	MTC 1990 Assigned
7902	7904	I-580 Westbound	101(Eureka/SF)	Francisco/Bellam	1432	1459
2223	1984	Hwy 4 Eastbound	I-80	Willow Ave.	1416	1213
2119	11550	Hwy 4 Eastbound	Cummings Skyway	McEwen Rd.	2809	2106
11550	2118	Hwy 4 Eastbound	McEwen Rd.	Alhambra Ave.	2813	2106
2159	2161	Hwy 4 Eastbound	Center St/Pine St. (Martinez)	Morello Rd.	2727	2164
1737	1726	Hwy 4 Eastbound	Willow Pass	E. Port Chicago Hwy	1865	1955
1637	1635	Hwy 4 Eastbound	Bailey Rd	Railroad Ave.	2350	1930
2160	2158	Hwy 4 Westbound	Morello Rd.	Center St/Pine St. (Martinez)	2388	2021
2202	11549	Hwy 4 Westbound	Alhambra Ave.	McEwen Rd.	1236	1512
11549	2203	Hwy 4 Westbound	McEwen Rd.	Cummings Skyway	1298	1512
3006	3004	Hwy 13 Southbound	Broadway Terrace	Moraga/Thornhill	2218	3236
3033	3005	Hwy 13 Northbound	Moraga/Thornhill	Broadway Terrace	2735	3141
3138	3130	Hwy 13 Northbound	580	Carson St./Redwood Rd.	2019	2539
1917	1915	Hwy 24 Westbound	680 North	680 North Merge	7390	4050
1850	2208	Hwy 24 Westbound	Acalanes	St. Stephens/Hidden Valley	7440	9694
2114	1847	Hwy 24 Westbound	St. Stephens/Hidden Valley	Orinda BART/Camino Pablo	9175	9749
1854	2565	Hwy 24 Westbound	Fish Ranch Rd.	Caldecott	8784	10076
2566	1837	Hwy 24 Eastbound	Caldecott	Fish Ranch Rd.	3795	4545
1833	2072	Hwy 24 Eastbound	Orinda BART/Camino Pablo	St. Stephens/Hidden Valley	4250	4929
1888	1950	Hwy 24 Eastbound	680 North Split	680 North	6076	3744
7322	7323	Hwy 101 Southbound	North Golden GateBr.	Golden Gate Br. Toll	6500	8617
7374	7093	Hwy 101 Southbound	Vermont	Army St./Potrero	8206	7359
6728	6731	Hwy 101 Southbound	Paul Ave.	Third St./Bayshore	9282	6856
6584	6593	Hwy 101 Southbound	South Airport	380/San Bruno	4744	6309
5962	5963	Hwy 101 Southbound	84 East/Willow	University (Palo Alto)	6264	5782
5269	5270	Hwy 101 Southbound	N. First St./Brokaw	880	3753	1673
5007	5720	Hwy 101 Northbound	McKee/Julian	Old Oakland Rd/13th	4553	9122
7094	7375	Hwy 101 Northbound	Army St./Potrero	Vermont	9050	9208
7320	7319	Hwy 101 Northbound	Golden Gate Br. Toll	North Golden GateBr.	2211	2656

* Observed values were obtained from Caltrans District 4, which assembled them from Caltrans data and consultant studies conducted between 1989 and 1991. For some links, counts and assigned volumes were available, but endpoints of links for which observations were recorded differed from MTC link definitions, or comprised several MTC links. In each of those cases, the assigned value in the table is for the link judged most likely to match the measurement point. In several cases, observation locations could not be matched to MTC links, because of simplifications made in coding the MTC network; these data were omitted from the table entirely.

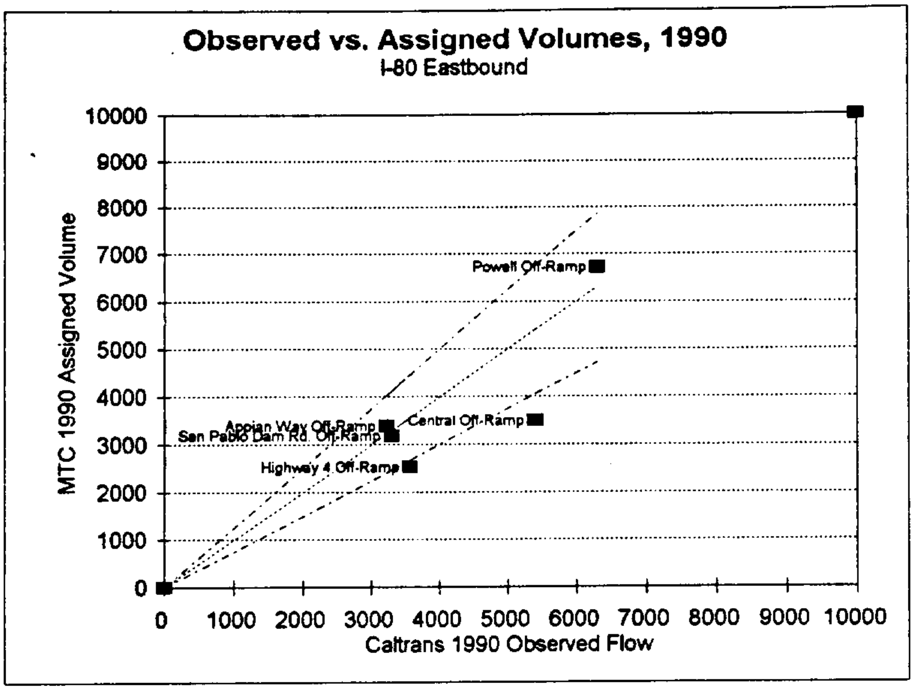
The MTC assignment is for the AM peak hour; hourly observations were available for most observation points. The "Observed" column in the table shows the observed value for 7-8 am, unless the value for 6-7am or for 8-9 am hour was much closer to the MTC value.

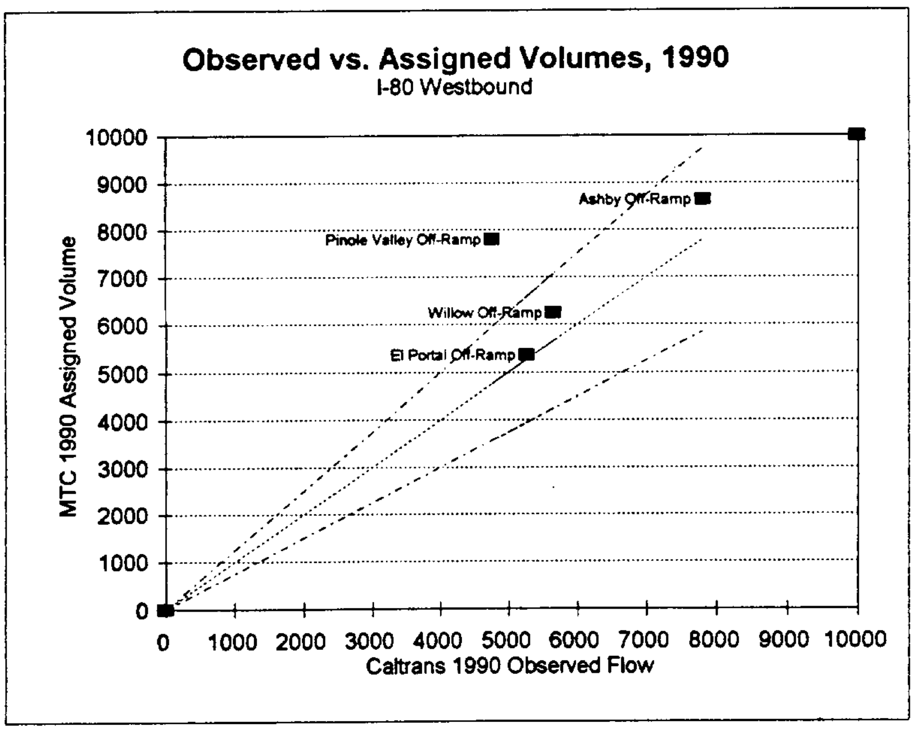
The reader should bear in mind that the assigned values are the output of a regional model, for a rather generically defined peak hour, and not for a particular clock hour. An exact match to ground counts for particular links during particular hours is not expected, the goal is a good fit regionwide and for long multi-link road segments.

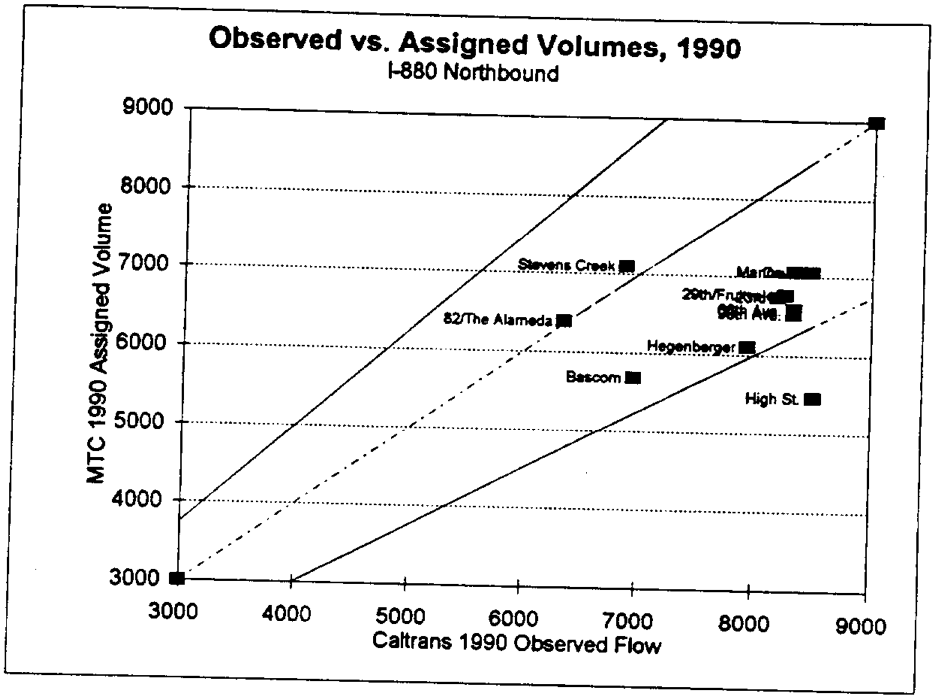
The assigned values included in this table are the output of a 4-iteration equilibrium, tolerance 0.01 MINUTP ASSIGN assignment run, using MTC's ASSM1120.SET setup. The speed-flow coefficient for both freeways and arterials was 0.2, the exponent for both 10.

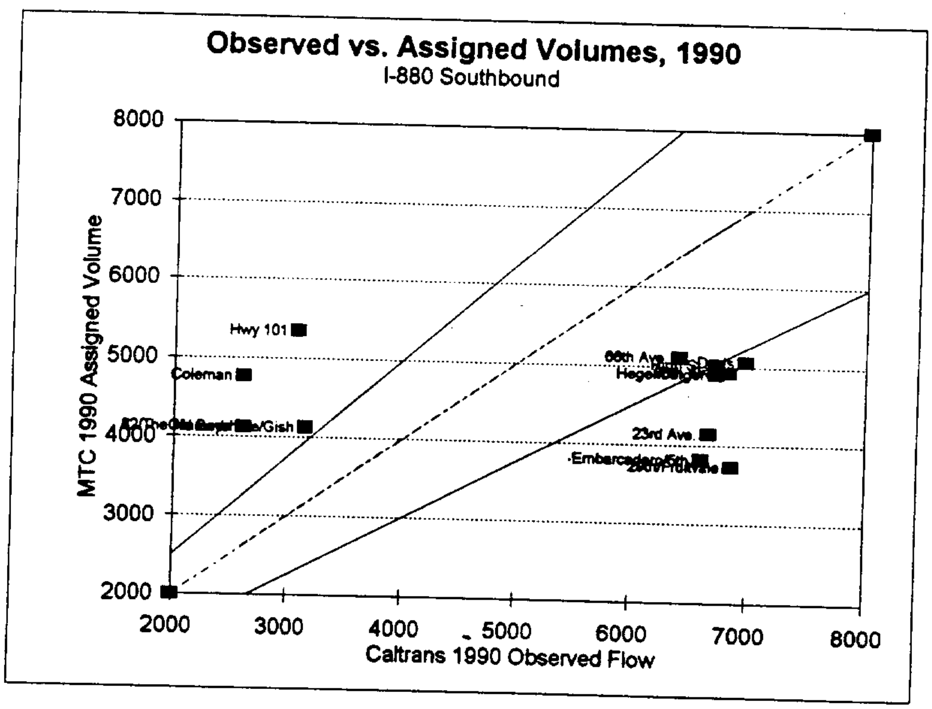


Observed vs. Assigned Volumes, 1990
83 Selected Freeway Links
MTC 1990 Assigned Volume
Caltrans 1990 Observed Flow
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000


Observed vs. Assigned Volumes, 1990
I-80 Eastbound
MTC 1990 Assigned Volume
Caltrans 1990 Observed Flow
Powell Off-Ramp
Appian Way Off-Ramp
San Pablo Dam Rd. Off-Ramp
Central Off-Ramp
Highway 4 Off-Ramp
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

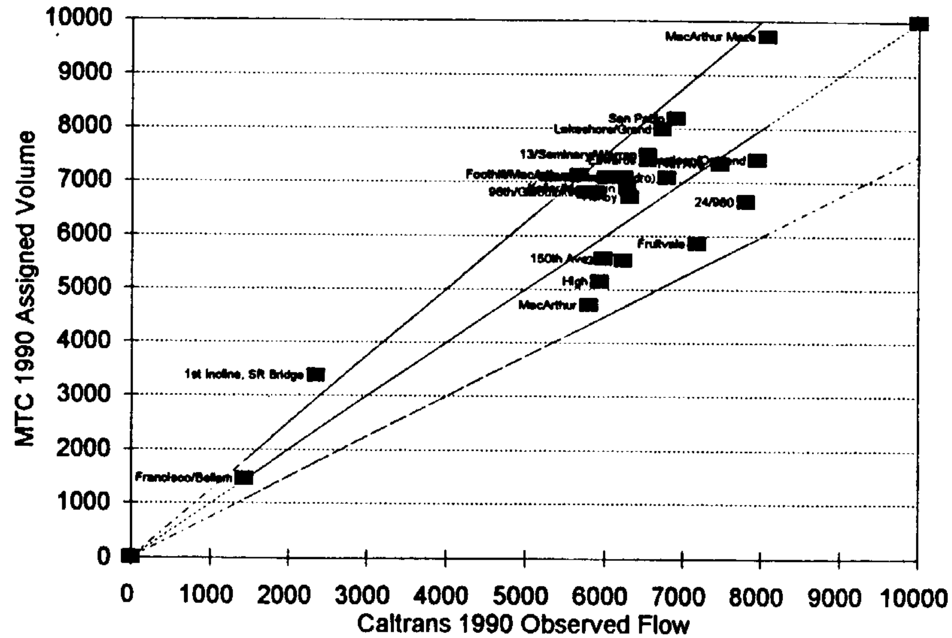

Observed vs. Assigned Volumes, 1990
I-80 Westbound
MTC 1990 Assigned Volume
Caltrans 1990 Observed Flow
Ashby Off-Ramp
Pinole Valley Off-Ramp
Willow Off-Ramp
El Portal Off-Ramp
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

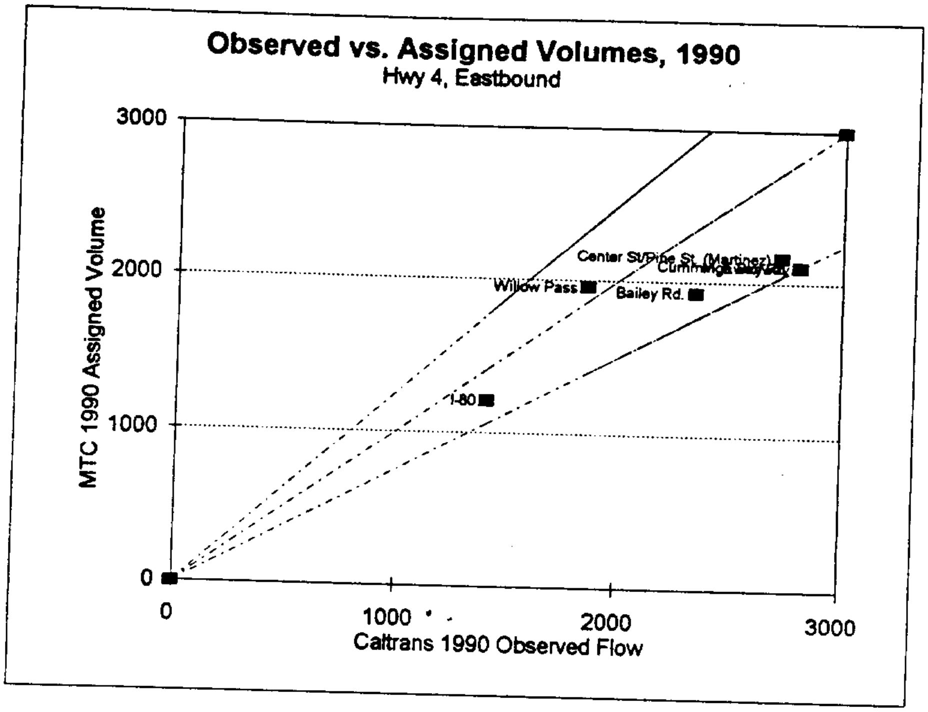

Observed vs. Assigned Volumes, 1990
I-880 Northbound
MTC 1990 Assigned Volume
Caltrans 1990 Observed Flow
9000
8000
7000
6000
5000
4000
3000
3000
4000
5000
6000
7000
8000
9000
Stevens Creek
82/The Alameda
98th Ave.
Hegenberger
Bascom
High St.

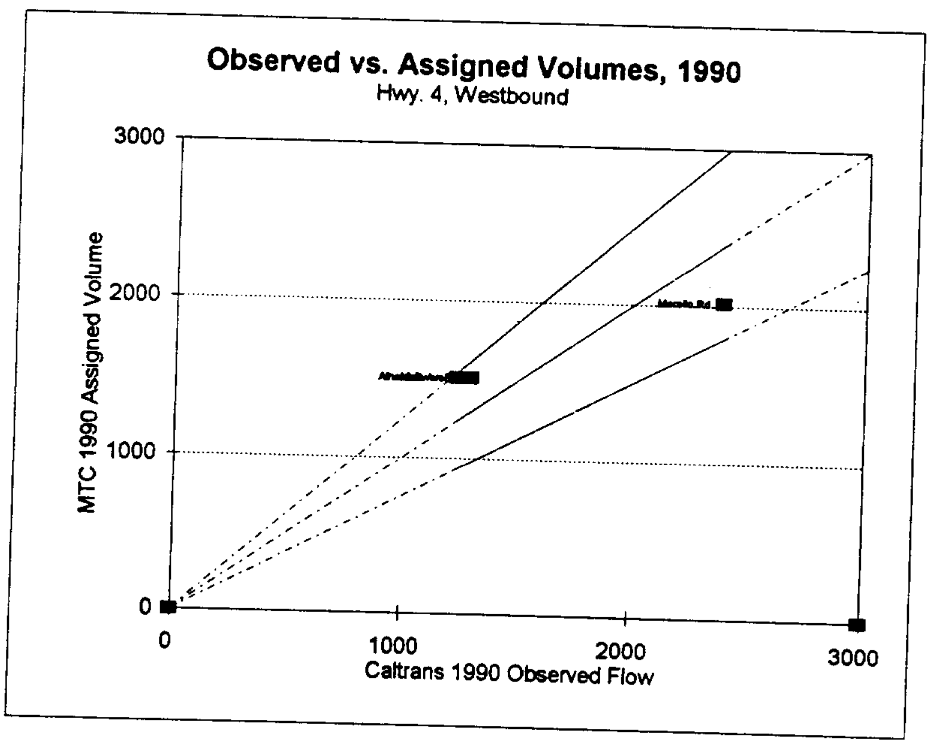

Observed vs. Assigned Volumes, 1990
I-880 Southbound
MTC 1990 Assigned Volume
Caltrans 1990 Observed Flow
8000
7000
6000
5000
4000
3000
2000
2000
3000
4000
5000
6000
7000
8000
Hwy 101
Coleman
66th Ave.
23rd Ave.

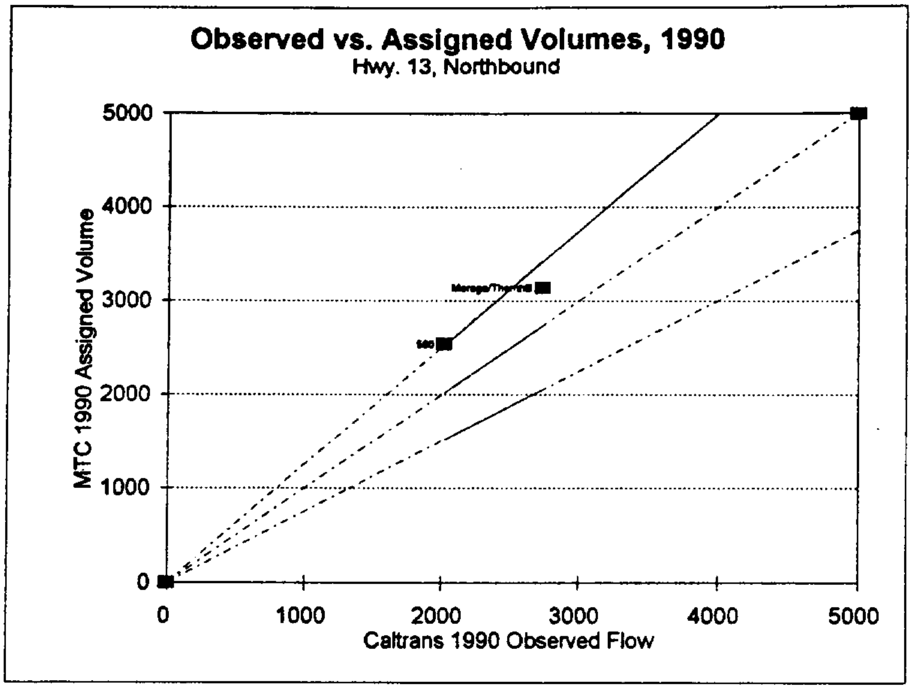
Observed vs. Assigned Volumes, 1990

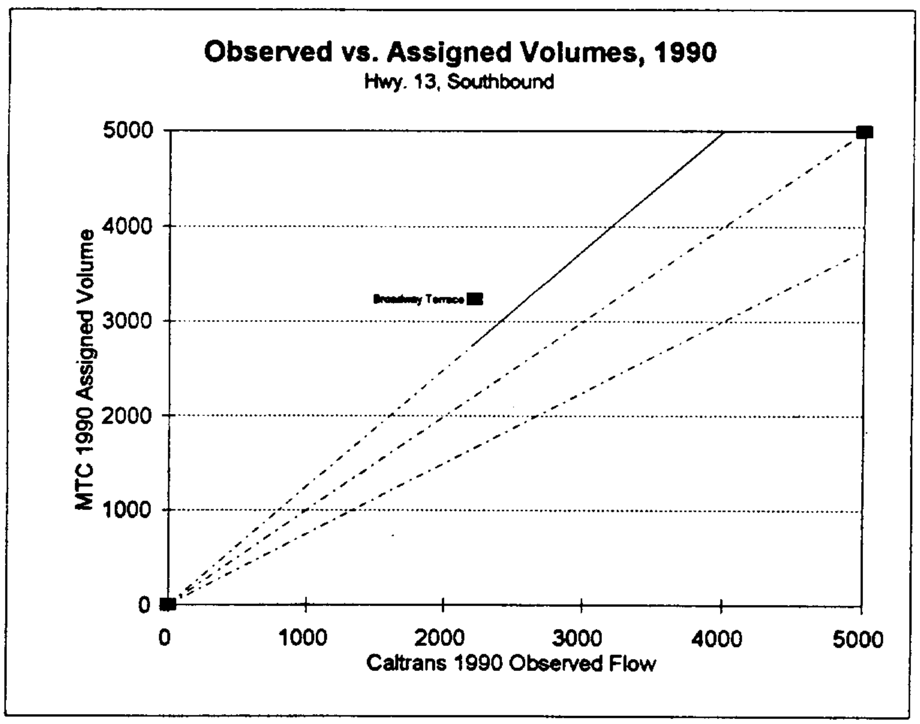
I-580, Westbound

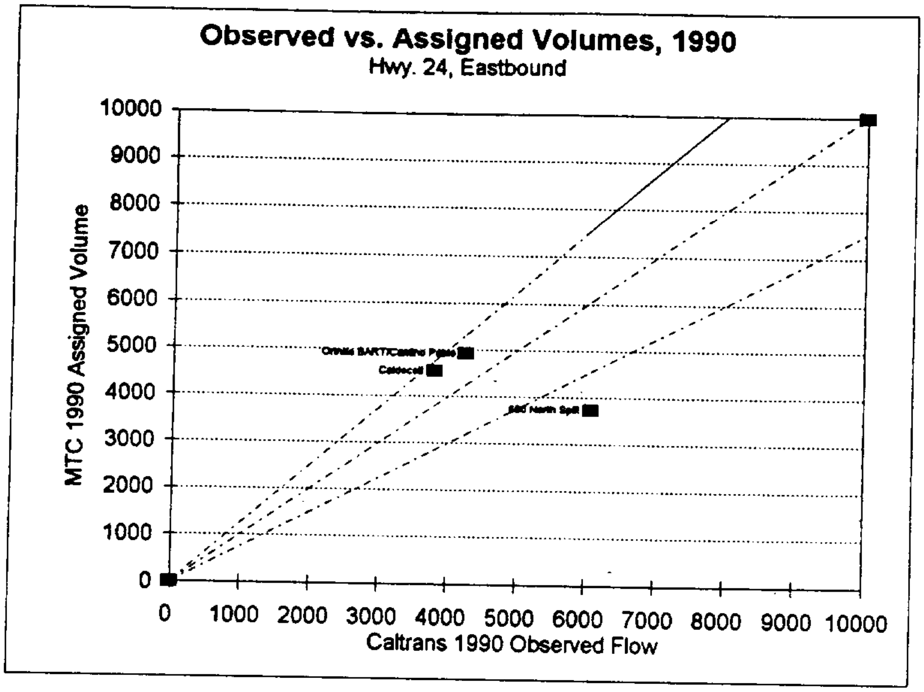


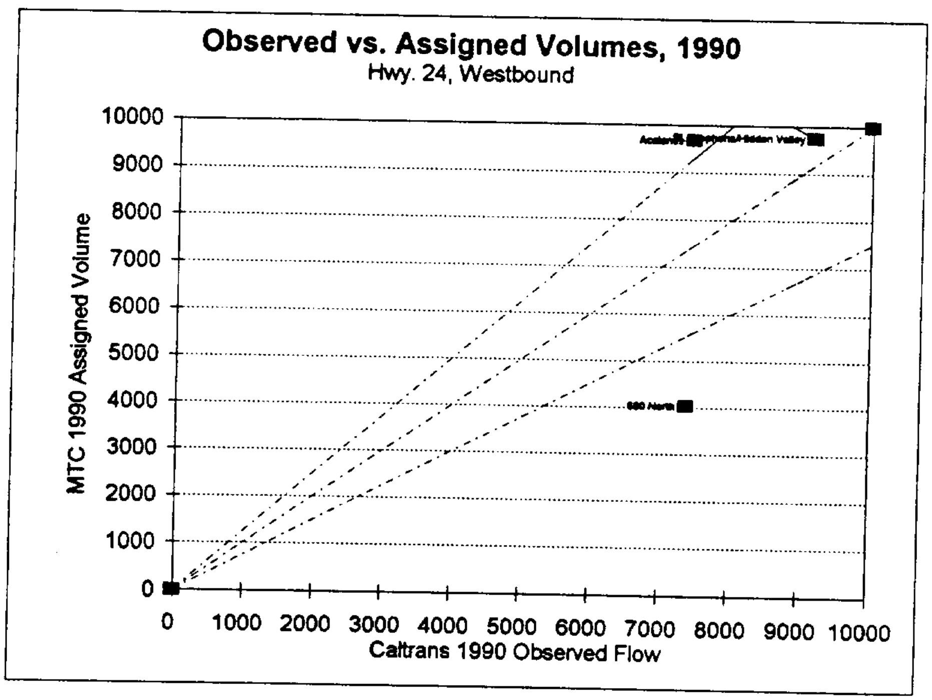

Observed vs. Assigned Volumes, 1990
Hwy 4, Eastbound
MTC 1990 Assigned Volume
Caltrans 1990 Observed Flow
0
1000
2000
3000
Center St/Pine St. (Martinez)
Willow Pass
Bailey Rd.
I-80

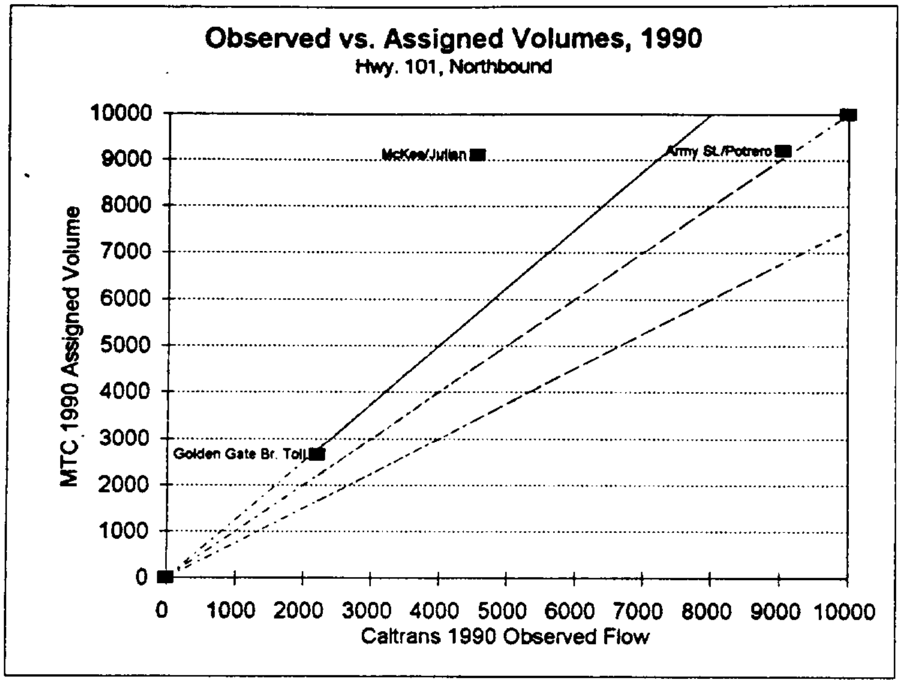

Observed vs. Assigned Volumes, 1990
Hwy. 4, Westbound
MTC 1990 Assigned Volume
Caltrans 1990 Observed Flow
0
1000
2000
3000


Observed vs. Assigned Volumes, 1990
Hwy. 13, Northbound
MTC 1990 Assigned Volume
0
1000
2000
3000
4000
5000
Caltrans 1990 Observed Flow


Observed vs. Assigned Volumes, 1990
Hwy. 13, Southbound
MTC 1990 Assigned Volume
0
1000
2000
3000
4000
5000
Broadway Terrace
Caltrans 1990 Observed Flow


Observed vs. Assigned Volumes, 1990
Hwy. 24, Eastbound
MTC 1990 Assigned Volume
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Caltrans 1990 Observed Flow


Observed vs. Assigned Volumes, 1990
Hwy. 24, Westbound
MTC 1990 Assigned Volume
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Caltrans 1990 Observed Flow


Observed vs. Assigned Volumes, 1990
Hwy. 101, Northbound
MTC 1990 Assigned Volume
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
McKee/Julian
Army St./Potrero
Golden Gate Br. Toll
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Caltrans 1990 Observed Flow

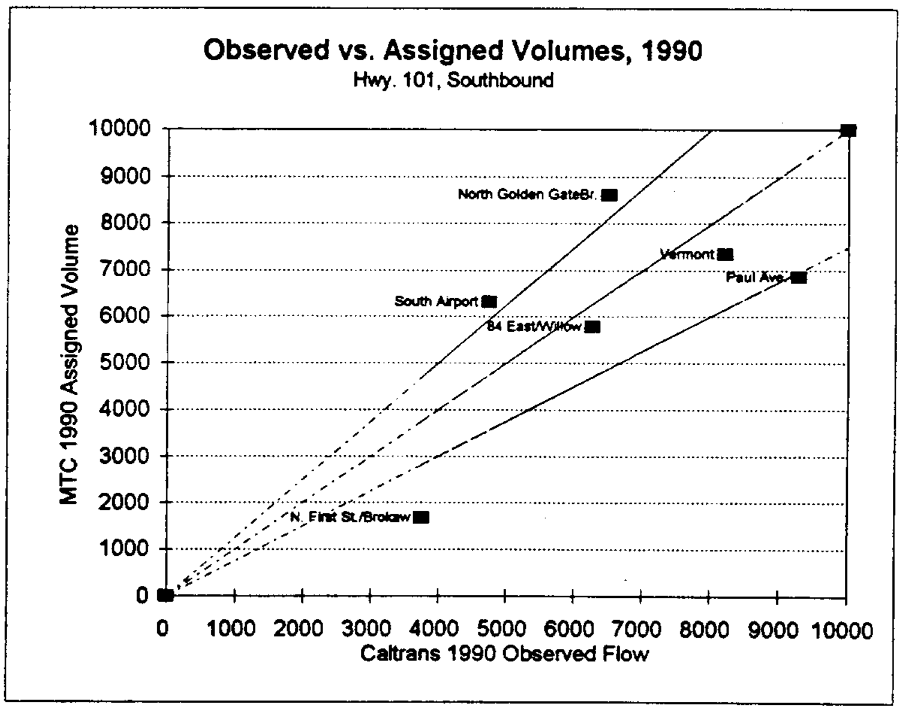

Observed vs. Assigned Volumes, 1990
Hwy. 101, Southbound
MTC 1990 Assigned Volume
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
North Golden GateBr.
Vermont
Paul Ave.
South Airport
84 East/Willow
N. First St./Brokaw
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Caltrans 1990 Observed Flow

TABLE C.2 AVERAGE TRAVEL SPEEDS: OBSERVED .vs PREDICTED VALUES

Observed Speeds (April 1991-92 Observations) Vs ARB Study Alternative Assignment 1
ARB Study Alternative Assigment 1: Congested Speed = (0.8* FFS)/(1+1*(V/C)10) for all links**
No other changes from MTC Assignment Setup ASSM1120 (AM Pk Hour, 4 Iter equilibrium)

	A-Node	B-Node	Observed Travel Dist Mi.	Peak Hour Speed (mph) Low	High	Avg	Observ. Date	Org. Speed (mph)	Obs vs. Org.: OK/Abs Diff.	Network Dist. miles	ARB Network Cong. Time (mins)	ARB Network Cong. Speed (mph)	Obs vs. Test : OK/Abs Diff.
RTE-4 CONTRA COSTA (I-80 to I-680)													
AM WB													
I-680->Alhambra	2147	2202	3.5	55	55	55	May-91	48	-7	3.25	3.03	64	0
Alhambra->Cummings	2202	2182	3.6	55	55	55	Apr-91	50	-5	3.83	3.57	64	0
Cummings->I-80	2182	2223	4.8	55	55	55	Apr-91	35	-20	4.43	6.64	40	-15
TOTAL			11.9	55	55	55		43	-12	11.50	13.24	52	-3
RTE-4 CONTRA COSTA (I-680 to Antioch Brige Toll Plaza)													
WB AM													
Wilbur ->Hillcrest	1674	1694	3.1	55	55	55	Oct-91	46	-9	2.92	2.89	61	0
Hillcrest->Loveridge	1694	1654	4.7	31	47	39	Oct-91	38	OK	4.42	6.75	39	OK
Loveridge->Bailey	1654	1618	4.1	21	27	24	Jun-91	30	3	4.08	14.84	16	-5
Bailey->Rte. 242	1618	2168	5.6	43	45	44	Oct-91	33	-10	5.43	17.10	19	-24
Rte. 242 -> I-680	2168	2147	1.9	54	54	54	May-91	48	-6	1.99	1.92	62	8
TOTAL			19.4	34	42	38		36	OK	18.80	43.50	26	-8
RTE 13 - ALAMEDA (I-580 to Rte 24)													
SB AM													
Rte. 24 -> I-580	3014	3083	6.0	55	55	55	Dec-91	45	-10	6.03	6.52	55	0
RTE 17 - SANTA CLARA (Summit Rd to Stevens Creek)													
NB AM													
Summit -> Saratoga	4289	4583	7.1	50	50	50		26	-24	6.92	7.89	53	3
Saratoga -> I-280	4583	5146	7.3	31	37	34		33	OK	7.23	12.04	36	OK
TOTAL			14.4	38	42	40		29	-9	14.20	19.93	43	1
RTE 24 - ALAMEDA (I-580/I-980 JCT. to I-680)													
WB AM													
Acalanes -> Rte 13	1850	3013	5.5	41	47	44		33	-8	5.25	14.05	22	-19
Rte 13 -> I-580/I-980	3013	2735	3.5	53	55	54		37	-16	3.98	4.25	56	1
TOTAL			9.0	45	50	48		35	-10	9.20	18.30	30	-15
EB AM													
I-580\I-980 -> Rte 13	2736	3022	3.0	36	55	46	Dec-91	47	OK	3.65	3.58	61	0
Rte 13 -> Acalanes	3022	1822	5.5	32	37	35	Jun-91	46	9	5.45	6.98	47	10
TOTAL			8.5	33	41	37		46	5	9.10	10.56	52	11
RTE 37- MARIN/SONOMA (US-101 to Rte 121)													
WB AM													
Rte 121 -> Atherton	8279	8038	4.7	55	55	55	Oct-88	49	-6	5.08	4.57	67	0
Atherton -> US-101	8038	8062	2.9	54	54	54	Oct-88	49	-5	2.16	1.99	65	11
TOTAL			7.6	55	55	55		49	-6	7.20	6.56	66	11
I-80 ALAMEDA/SAN FRANCISCO (Carquinez Br. to US 101)													
WB AM													
Carquinez Br. -> Rte 4	1273	2222	5.0	55	55	55	May-91	35	-20	4.92	18.50	16	-39
Rte 4 -> El Portal	2222	2260	4.9	23	24	24	Apr-91	27	3	5.47	23.31	14	-9
El Portal -> I-580	2260	2483	5.4	24	26	25	Mar-91	29	3	5.82	43.69	8	-16
I-580 -> I-880	2483	2764	4.5	28	34	31	Nov-91	28	OK	3.64	14.01	16	-12
I-880 -> I-480	2764	7016	6.7	18	19	19	Apr-90	32	13	6.57	38.09	10	-8
I-480 -> US-101	7016	7040	1.2	51	51	51	Apr-91	32	-19	1.44	2.43	36	-15
TOTAL			27.7	25	27	26		30	3	27.90	140.03	12	-13
EB AM													
US-101 -> I-480	7039	7017	1.8	24	34	29	Apr-91	40	6	1.40	6.36	13	-11
I-480 -> I-880	7017	2778	6.5	50	50	50	Sep-90	46	-4	6.51	7.66	51	1
I-880 -> I-580	2778	2482	4.1	55	55	55	Nov-91	44	-11	3.77	4.47	51	-4
TOTAL			12.4	44	48	46		44	OK	11.70	18.49	38	-8

TABLE C.2 (Cont..)

	A-Node	B-Node	Observed Travel: Dist Mi.	Peak Hour Speed (mph): Low	High	Avg	Observ. Date	Org. Speed (mph)	Obs vs. Org.: OK/Abs Diff.	Network Dist. miles	ARB Network Cong. Time (mins)	ARB Network Cong. Speed (mph)	Obs vs. Test: OK/Abs Diff.
RTE 84 - ALAMEDA/SAN MATEO (I-880 -> US-101)													
WB AM													
I-880 -> ALA/SM line	3886	5938	5.9	16	19	18	Oct-91	27	8	5.84	15.79	22	3
ALA/SM line -> US-101	5938	5961	4.2	51	51	51	Oct-91	33	-18	3.41	6.97	29	-22
TOTAL			10.1	23	26	24		29	4	9.30	22.76	25	OK
RTE 85 - SANTA CLARA (US-101 to I-280)													
NB AM													
I-280 -> US-101	4666	5641	5.9	40	45	43	Sep-90	37	-3	6.21	13.34	28	-12
RTE 92 - ALAMEDA/SAN MATEO (I-880 to I-280)													
WB AM													
I-880 -> ALA/SM line	3634	6381	6.3	25	29	27	Mar-91	39	10	6.31	18.42	21	-4
ALA/SM line->US-101	6381	6347	6.8	55	55	55	Oct-91	43	-12	6.74	10.61	38	-17
US-101 -> I-280	6347	6233	5.0	48	55	52	May-91	48	OK	4.33	4.46	58	0
TOTAL			18.1	38	42	40		43	1	17.40	33.49	31	-7
US-101 - SANTA CLARA (Rte 152 to Willow)													
NB AM													
Rte 152 -> San Martin	4183	4204	6.4	55	55	55	Jun-91	48	-7	6.02	5.68	64	0
San Martin->Cochrane	4204	4272	5.4	55	55	55	Jun-91	47	-8	5.01	4.96	61	0
Cochrane -> Bailey	4272	5078	5.6	55	55	55	May-91	42	-13	5.19	5.68	55	0
Baley -> Hellyer	5078	4379	6.6	53	55	54	Feb-91	42	-11	9.12	10.74	51	-2
Hellyer -> I-680	4379	5028	5.0	29	33	31	Oct-90	23	-6	4.88	374.66	1	-28
I-680 -> I-880	5028	5690	3.2	14	16	15	Oct-90	16	OK	3.24	663.87	0	-14
I-880->Great America	5690	5602	4.7	29	33	31	May-91	27	-2	4.72	295.14	1	-28
Great America->Rt237	5602	5825	3.3	55	55	55	Dec-90	37	-18	3.33	96.34	2	-53
Rte 237 -> Rte 85	5825	5641	2.1	55	55	55	Nov-90	46	-9	2.21	3.03	44	-11
Rte 85 -> Willow	5641	5936	6.2	50	55	53	Dec-91	40	-10	6.02	19.30	19	-31
TOTAL			48.5	40	42	41		34	-6	48.30	1479.40	2	-38
US-101- SAN MATEO (Willow to Harney)													
NB AM													
Willow -> Whipple	5936	6194	4.6	54	54	54	Jun-90	41	-13	4.77	6.46	44	-10
Rte 92 -> Broadway	6374	6540	4.8	34	44	39	Nov-91	37	OK	4.74	9.56	30	-4
Broadway -> I-380	6540	6592	4.2	55	55	55	Dec-90	42	-13	4.32	6.04	43	-12
I-380 -> Harney	6592	6733	4.9	55	55	55	Mar-91	41	-14	5.76	6.75	51	-4
TOTAL			18.5	47	52	50		40	-7	19.60	28.81	41	-6
SB AM													
Broadway ->Rte 92	6408	6359	4.8	55	55	55	Nov-91	44	-11	4.87	5.27	55	0
Rte 92 -> Whipple	6359	6115	5.2	37	52	45	Oct-91	42	OK	4.85	5.66	51	OK
Whipple -> Willow	6115	5962	4.8	39	42	41	Mar-90	40	OK	4.75	5.78	49	7
TOTAL			14.8	42	49	46		42	OK	14.50	16.71	52	3
US-101 - SAN FRANCISCO (Harney to Golden Gate Ave.)													
NB AM													
Harney -> I-280	6733	6922	2.5	13	16	15	Apr-91	45	29	2.30	161.18	1	-12
I-280 -> I-80	6922	7077	2.5	22	27	25	Apr-91	20	-2	2.46	160.14	1	-21
I-80->Golden Gate Av	7077	7192	1.4	18	22	20	Jan-91	46	24	0.91	1.82	30	8
TOTAL			6.4	17	20	19		30	10	5.70	323.14	1	-18
SB AM													
Turk -> I-80	7191	7060	1.8	14	27	21	Jan-91	46	19	1.30	2.40	33	6
I-80 -> I-280	7060	6804	2.9	50	50	50	Sep-91	39	-11	3.00	4.07	44	-6
I-280 -> Harney	6804	5990	1.6	56	56	56	Apr-91	41	-15	1.45	1.72	51	-5
TOTAL			6.3	29	41	35		41	OK	5.80	8.19	42	1

TABLE C.2 (Cont.)

	A-Node	B-Node	Dist Mi.	Observed Travel Peak Hour Speed (mph) Low	High	Avg	Observ. Date	Org. Speed (mph)	Obs vs. Org.: OK/Abs Diff.	Network Dist. miles	ARB Network Cong. Time (mins)	ARB Network Cong. Speed (mph)	Obs vs. Test : OK/Abs Diff.
US-101 - MARIN/SONOMA (El Presidio to River Rd)													
SB AM													
River Rd -> Rte 12	8344	8426	5.3	53	55	54	Nov-90	38	-15	4.95	6.55	45	-8
Rte 12 -> Rte 116	8426	8265	6.9	55	55	55	Apr-90	40	-15	6.96	9.16	46	-9
Rt.116->Old Redwood	8265	8262	5.0	55	55	55	Apr-90	43	-12	4.86	5.74	51	-4
Old Redwood->Rt.116	8262	8207	3.8	54	54	54	Apr-90	42	-12	4.33	4.78	54	0
Rt.116->Redwood San.	8207	8202	6.0	55	55	55	Apr-90	36	-19	3.90	7.75	30	-25
Redwood San.->Rt.37	8202	7975	6.6	55	55	55	Feb-92	37	-18	8.90	14.79	36	-19
Rte.37 -> Lucas Valley	7975	7951	4.1	23	25	24	Dec-91	22	-1	4.01	38.88	6	-17
Lucas Valley -> I-580	7951	7901	4.5	28	32	30	Oct-91	27	-1	4.47	14.71	18	-10
I-580 -> Rte. 1	7901	7822	6.1	46	49	48	Nov-91	37	-9	6.34	16.20	23	-23
Rte. 1 -> El Presidio	7822	7327	6.3	30	36	33	Feb-91	43	7	7.06	22.59	19	-11
TOTAL			54.6	42	45	44		36	-6	55.80	141.15	24	-18
NB AM													
El Presidio -> Rte.1	7324	7821	6.0	51	51	51	Feb-91	50	-1	6.33	6.10	62	0
RTE. 237 - SANTA CLARA (I-680 to Rte. 85)													
WB AM													
I-680 -> I-880	5779	5838	1.7	8	10	9	Nov-90	24	14	1.98	4.12	29	19
I-880 -> US-101	5838	5825	6.7	31	34	33	Nov-90	19	-12	7.05	34.24	12	-19
TOTAL			8.4	20	23	22		20	OK	9.00	38.36	14	-6
RTE 238 - ALAMEDA (I-580 to I-880)													
NB AM													
I-580 -> I-880	3478	3377	2.1	20	28	24	Dec-91	35	7	2.45	3.98	37	9
RTE 242 - CONTRA COSTA (Rte 4 to I-680)													
WB AM													
Rte. 4 -> I-680	2165	2074	4.4	23	26	25	May-91	37	11	4.65	10.82	26	OK
I-280 SANTA CLARA (Alpine Rd to US-101)													
NB AM													
Rte. 85 -> I-880	4667	4866	6.5	44	49	47	Oct-91	44	OK	6.68	7.94	50	1
I-880 -> Rte 87	4866	4939	3.0	55	55	55	Dec-91	45	-10	2.99	2.99	60	0
Rte 87 -> US-101	4939	5249	2.6	56	56	56	Dec-91	32	-24	2.95	2.95	60	0
TOTAL			12.1	49	52	51		41	-8	11.70	13.88	51	OK
SB AM													
US-101 -> Rte. 87	4486	5192	2.5	56	56	56	Dec-91	35	-21	2.02	2.97	41	-15
Rte. 87 -> I-880	5192	4822	2.9	22	23	23	Jun-87	42	19	3.04	3.14	58	0
I-880 -> Rte. 85	4822	4672	6.8	37	43	40	Sep-91	30	-7	6.72	23.61	17	-20
Rte. 85 ->El Monte	4672	4679	4.2	55	55	55	Dec-91	48	-7	4.91	4.84	61	0
El Monte -> Alpine	4679	5919	5.6	55	55	55	Dec-91	49	-6	5.51	5.12	66	0
TOTAL			22.0	41	43	42		39	-2	22.20	39.68	34	-7
I-280 SAN MATEO/SAN FRANCISCO (Alpine to US-101)													
NB AM													
Alpine -> Farm Hill	5919	6056	4.6	55	55	55	Dec-91	50	-5	4.55	4.19	65	0
Farm Hill -> Rte. 92	6056	6269	6.7	55	55	55	Dec-91	49	-6	6.97	6.52	64	0
Rte. 92 -> Trousdale	6269	6430	6.4	55	55	55	Dec-91	46	-9	6.70	7.45	54	-1
Trousdale -> I-380	6430	6505	3.9	54	54	54	Dec-91	48	-6	4.25	4.52	56	0
I-380 -> Rte. 1	6505	6652	4.3	55	55	55	Oct-90	48	-7	3.73	3.95	57	0
Rte. 1 -> US-101	6652	6922	6.5	23	28	26	Mar-90	44	16	6.12	76.57	5	-18
TOTAL			32.4	43	46	45		47	1	33.00	103.20	19	-24
I-380 - SAN MATEO													
EB AM													
I-280 -> US-101	6504	6592	2.3	37	53	45	Mar-91	42	OK	2.26	2.82	48	OK

TABLE C.2 (Cont..)

	A-Node	B-Node	Observed Travel Dist MI.	Peak Hour Speed (mph) Low	Peak Hour Speed (mph) High	Peak Hour Speed (mph) Avg	Observ. Date	Org. Speed (mph)	Obs vs. Org.: OK/Abs Diff.	Network Dist. miles	ARB Network Cong. Time (mins)	ARB Network Cong. * Speed (mph)	Obs vs. Test : OK/Abs Diff.
I-580 - ALAMEDA (Rte. 205 to I-80)													
WB AM													
Rte. 205 -> N.Flynn Rd	4110	2936	5.4	55	55	55	May-91	46	-9	5.86	5.62	60	0
N.Flynn Rd-> Rte. 84	2936	4098	4.6	55	55	55	May-91	46	-9	3.82	3.79	60	0
Rte. 84 -> Airway Blvd	4098	8316	4.3	55	55	55	Mar-91	43	-12	5.47	6.15	53	-2
Airway Blvd -> I-680	8316	3970	5.8	55	55	55	Mar-91	40	-15	6.86	8.94	46	-9
I-680 -> Eden Canyon	3970	3534	5.4	56	56	56	Jun-91	41	-15	5.30	7.58	42	-14
Eden Canyon-> Rt.238	3534	3478	4.5	53	53	53	Jun-91	43	-10	4.33	5.33	49	-4
Rte. 238 -> McArthur	3478	3354	4.3	56	56	56	Oct-91	47	-9	4.48	4.99	54	-2
McArthur -> Rte. 13	3354	3054	4.3	52	55	54	Mar-91	45	-7	3.47	4.28	49	-3
Rte. 13 -> Rte. 24	3054	2711	6.3	35	44	40	Nov-91	40	OK	7.26	8.78	50	6
TOTAL			46.2	47	50	49		42	-5	48.10	55.66	52	2
EB AM													
Rte. 80 -> Rte. 24	2767	2702	2.3	49	55	52	Oct-91	30	-19	1.86	3.36	33	-16
I-680 - SANTA CLARA / ALAMEDA (US-101 to I-580)													
SB AM													
I-580 ->Bernal	4029	4028	3.3	55	55	55	Jan-91	37	-18	3.38	3.19	64	0
Bernal -> Rte. 84	4028	4061	5.0	55	55	55	Jan-91	38	-17	5.01	4.68	64	0
Rte. 84 -> Rte.238	4051	3821	4.8	55	55	55	Jan-91	33	-22	4.70	11.29	25	-30
Rte.238 -> Scott Creek	3821	5773	6.4	25	28	27	Oct-91	46	18	7.00	7.56	56	28
Scott Creek -> Capitol	5773	5735	4.9	55	55	55	Dec-90	48	-7	5.28	5.27	60	0
Capitol -> US-101	5735	4486	5.3	55	55	55	May-91	41	-14	4.94	5.77	51	-4
TOTAL			29.7	43	46	45		41	-2	28.80	37.76	46	OK
I-680 ALAMEDA / CONTRA COSTA (I-580 to Rte. 24)													
NB AM													
I-580 -> Crow Canyon	3983	1739	6.0	55	55	55	Sep-91	48	-7	5.95	5.88	61	0
Crow Can.->Stone Val.	1739	1793	6.1	55	55	55	Mar-91	47	-8	6.39	6.53	59	4
Stone Valley->Rte.24	1793	1950	3.9	18	23	21	Dec-91	38	15	3.86	4.94	47	24
TOTAL			16.0	36	41	39		45	4	16.20	17.35	56	15
SB AM													
Rte 24 -> Stone Valley	1885	1764	4.0	26	33	30	Dec-91	33	OK	3.99	4.51	53	20
I-680 ALAMEDA / CONTRA COSTA (Rte 24 to Benicia Bridge)													
SB AM													
Benicia Toll P.->Rte.4	1203	2094	5.3	33	40	37	Oct-87	31	-2	5.42	27.21	12	-21
Rte. 4 -> Rte. 242	2094	2074	2.8	45	54	50	Nov-91	34	-11	2.65	4.53	35	-10
Rte 242 -> Rte. 24	2074	1885	4.3	16	18	17	Nov-91	28	10	4.36	30.92	8	-8
TOTAL			12.4	31	37	34		31	0	12.40	62.66	12	-19
NB AM													
Rte. 24 -> Rte. 242	1949	2036	4.3	55	55	55	Nov-91	42	-13	4.18	5.69	44	-11
I-880 SANTA CLARA / ALAMEDA (I-280 to Durham)													
SB AM													
Durham -> Rte 237	3855	5681	6.9	13	16	15	May-91	27	11	6.89	381.76	1	-12
Rte 237 -> US-101	5681	5271	4.2	55	55	55	Mar-88	38	-17	4.28	13.19	19	-36
TOTAL			11.1	19	22	21		30	8	11.20	394.95	2	-17
NB AM													
I-280 -> US-101	5146	5717	3.6	23	31	27	Oct-90	35	4	3.71	6.58	34	3
US-101 -> Rte. 237	5717	5796	4.4	39	43	41	Oct-90	37	-2	4.38	74.24	4	-35
TOTAL			8.0	30	36	33		36	OK	8.10	80.82	6	-24
I-880 ALAMEDA (Durham to I-980)													
NB AM													
Durham -> Decoto	3920	3745	5.6	55	55	55	May-91	45	-10	5.65	5.47	62	0
Decoto -> Rte. 92	3745	3597	6.5	21	28	25	Nov-87	31	3	6.63	22.07	18	-3
Rte. 92 -> Rte. 238	3597	3377	4.0	33	35	34	Jan-88	36	1	4.03	17.54	14	-19
Rt.238->Hegenberger	3377	3297	4.7	55	55	55	Sep-88	36	-19	4.74	8.27	34	-21
Hegenberg.->Jackson	3297	2826	5.8	55	55	55	Sep-91	40	-15	6.06	6.71	54	-1
TOTAL			26.6	37	42	40		37	OK	27.10	60.06	27	-10
I-980 ALAMEDA													
EB AM													
I-580/Rt.24 Jct -> I-880	2735	2805	1.6	56	56	56	Nov-91	40	-16	1.82	2.04	54	-2

Total Freeway locations: 119

Root Mean Square Error for Original Model Run : 12

Root Mean Square Error for ARB Alternative 1 : 14

APPENDIX D: AIRQMTC.SET COMMAND FILE FOR PROCESSING MINUTP OUTPUT

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$*************************************************************
$ FILE: AIRQMTC.SET       PROCESS DATA FOR THE AIRQ POST-PROCESSOR
$                  1120 ZONE 1990 AM PEAK MTC BASE NETWORK
$                  Version 1.1    A. Skabardonis June 1994
$*************************************************************
*PGM NETMRG LOAD28.NET LOAD27.NET
NET 0=OUTNET,1=LOAD27.NET
$
$
$ User Select the network links for processing
$ USE A=1122-15002,B=1122-15002
$ USE FT=2
$
 SKIP FT=6                    Skip Dummy Nodes
 IF VOL=1-99999                 Process links with volumes
$
$ Determine "LINK TYPE" (ID) for the Relationships in AIRQ program
$ Fwy-to-Fwy
  @ FT=1,AT=0-3 ID=1
  @ FT=1,AT=4-5 ID=2
$ Freeways
  @ FT=2 ID=2
$ Expressways
  @ FT=3,AT=0-1 ID=3
  @ FT=3,AT=2-5 ID=4
$ Collectors
  @ FT=4,AT=0-1 ID=5
  @ FT=4,AT=2-5 ID=6
$ Ramps
  @ FT=5,AT=0-1 ID=7
  @ FT=5,AT=2-5 ID=8
$ Arterials
  @ FT=7,AT=0-1 ID=9
  @ FT=7,AT=2-3 ID=10
  @ FT=7,AT=4   ID=11
  @ FT=7,AT=5   ID=4
$ Metered Ramps
  @ FT=8,AT=0-5 ID=12
$
$ Determine the Free-flow Speed (FFS) from SPDC/CAPC (1990 MTC network)
 @ FT=1,AT=0-1 FFS=40
 @ FT=1,AT=2-3 FFS=45
 @ FT=1,AT=4-5 FFS=50
 @ FT=2,AT=0-1 FFS=55
 @ FT=2,AT=2-3 FFS=60
 @ FT=2,AT=4-5 FFS=65
 @ FT=3,AT=0-1 FFS=40
 @ FT=3,AT=2-3 FFS=45
 @ FT=3,AT=4   FFS=50
 @ FT=3,AT=5   FFS=55
 @ FT=4,AT=0   FFS=20
```

```
 @ FT=4,AT=1   FFS=25
 @ FT=4,AT=2-3 FFS=30
 @ FT=4,AT=4   FFS=35
 @ FT=4,AT=5   FFS=40
 @ FT=5,AT=0-1 FFS=30
 @ FT=5,AT=2-3 FFS=35
 @ FT=5,AT=4-5 FFS=40
 @ FT=7,AT=0   FFS=25
 @ FT=7,AT=1   FFS=30
 @ FT=7,AT=2-3 FFS=35
 @ FT=7,AT=4   FFS=40
 @ FT=7,AT=5   FFS=45
 @ FT=8,AT=0-1 FFS=25
 @ FT=8,AT=2-3 FFS=30
 @ FT=8,AT=4-5 FFS=35
$
$ Calculate link capacity, VMT and VHT
$
 CAPA=CAP*LANE
 VMT=DIST*VOL                    (Veh-mi)*100
 VHT=VOL*CTIM                    (VEH-min)*100
$
$ Write Link Data to a File (Default Filename:AIRQINP.INP)
$
LIST A=1-5,B=6-10,DIST=11-15,FFS=16-20,CAPA=21-25,FT=26,AT=27
LIST VOL=28-32,CSPD=33-37,VC=38-42,ID=43-44
LIST VMT=50-58,VHT=59-67
ENDIF                    FOR VOL=1-99999
$
LSTO 2,AIRQINP.INP
*>COPY *.PRN  RESULTS.OUT
*>DEL *.PRN
*>LIST AIRQINP.INP
$
$ Run the AIRQ Post-Processor (Off-line)
$*>AIRQO
$
$******************************************************************
```

APPENDIX E: SOURCE CODE FOR THE AIRQ PROGRAM

```
      PROGRAM AIRQI
C*******************************************************************
C Processing of MINUTP Model Output
C Estimation of Time-Spent in Each Driving Mode
C Based on the relationships from simulation experiments
C Base Relationships speed-acceleration in look-up tables
C (I): INTERACTIVE PROGRAM VERSION     A. SKABARDONIS   1994
C VERSION 1.1 5/94
C VERSION 1.2 9/94
C*******************************************************************
C AIRQI-MAIN
C Program Menus/File Specification
C
C Interactive Menu
      COMMON/BLK4/IFLAG
      CHARACTER*15 FNAME
      CHARACTER*14 INNAME
      CHARACTER*1  INFILE(14),YESNO
      EQUIVALENCE (INNAME, INFILE)
      LOGICAL*4 EXISTS
C
C  START OF MENU LOOP
 1000 CONTINUE
      DO 2 I=1,14
      INFILE(I)=' '
    2 CONTINUE
C
C END OF INITIALIZING. DISPLAY MENU.
      CALL CLRSCR
      WRITE(*,*) ' '
      WRITE(*,3002)
      WRITE(*,3004)
      WRITE(*,3006)
      WRITE(*,3004)
      WRITE(*,3008)
      WRITE (*,*) ' '
      WRITE (*,3010)
      READ (*,'(BN,I1)') IPICK
      GOTO (4010,4020,4030,4040,4050) IPICK
      GOTO 1000
C
C--Open Input/Output Files
C     UNIT 2:  Input file with link characteristics
C     UNIT 5:  Network statistics (TABLE1)
C     UNIT 3:  Link/network summary performance (TABLE2-OPTIONAL)
C     UNIT 4:  Link specific veh activity (TABLE3-OPTIONAL)
C
 4010 WRITE (*,3012)
      READ (*,3014) FNAME
      INQUIRE (FILE=FNAME,EXIST=EXISTS)
      IF (.NOT. EXISTS) THEN
        WRITE (*,3016)
        READ (*,3018) YESNO
```

```
      IF (YESNO .EQ. 'R' .OR. YESNO .EQ. 'r') GO TO 4010
      GOTO 5000
     ELSE
     OPEN (2,FILE=FNAME, ACCESS='SEQUENTIAL')
     ENDIF
C
     IFLAG=0
 2000 WRITE (*,3020)
     READ (*,3014) FNAME
     INQUIRE (FILE=FNAME,EXIST=EXISTS)
     IF (EXISTS) THEN
        WRITE (*,3022)
        READ (*,3018) YESNO
        IF (YESNO .EQ. 'R' .OR. YESNO .EQ. 'r') GO TO 2000
        IF (YESNO .EQ. 'O' .OR. YESNO .EQ. 'o') GO TO 2100
        GOTO 5000
     ENDIF
 2100 OPEN (5,FILE=FNAME,FORM='FORMATTED',STATUS='UNKNOWN')
     OPEN (8,FILE='TABLE1.BAT',STATUS='UNKNOWN')
     WRITE(8,3030) FNAME
C
     WRITE (*,3032)
     READ (*,3018) YESNO
     IF (YESNO.NE.'Y' .AND. YESNO.NE.'y') GOTO 2400
 2200 WRITE(*,3028)
     READ (*,3014) FNAME
     INQUIRE (FILE=FNAME,EXIST=EXISTS)
     IF (EXISTS) THEN
        WRITE (*,3022)
        READ (*,3018) YESNO
        IF (YESNO .EQ. 'R' .OR. YESNO .EQ. 'r') GO TO 2200
        IF (YESNO .EQ. 'O' .OR. YESNO .EQ. 'o') GO TO 2300
        GOTO 5000
     ENDIF
 2300 OPEN (3,FILE=FNAME,FORM='FORMATTED',STATUS='UNKNOWN')
     OPEN (8,FILE='TABLE2.BAT',STATUS='UNKNOWN')
     WRITE (8,3030) FNAME
     IFLAG=1
C
 2400 WRITE (*,3026)
     READ (*,3018) YESNO
     IF (YESNO .NE. 'Y' .AND. YESNO .NE. 'y') GO TO 2700
 2500 WRITE (*,3028)
     READ (*,3014) FNAME
     INQUIRE (FILE=FNAME,EXIST=EXISTS)
     IF (EXISTS) THEN
        WRITE (0,3022)
        READ (0,3018) YESNO
        IF (YESNO .EQ. 'R' .OR. YESNO .EQ. 'r') GO TO 2500
        IF (YESNO .EQ. 'O' .OR. YESNO .EQ. 'o') GO TO 2600
        GOTO 5000
     ENDIF
 2600 OPEN (4,FILE=FNAME,FORM='FORMATTED',STATUS='UNKNOWN')
     OPEN (8,FILE='TABLE3.BAT',STATUS='NEW')
     WRITE (8,3030) FNAME
     IFLAG=2
```

```
2700 WRITE (*,3040)
     CALL AIRQM
     OPEN(7,FILE='&PAT1.XXX',STATUS='UNKNOWN')
     CLOSE(7,STATUS='KEEP')
     GOTO 5000
4020 OPEN(7,FILE='&PAT2.XXX',STATUS='NEW')
     CLOSE(7,STATUS='KEEP')
     GOTO 5000
4030 OPEN(7,FILE='&PAT3.XXX',STATUS='NEW')
     CLOSE(7,STATUS='KEEP')
     GOTO 5000
4040 OPEN(7,FILE='&PAT4.XXX',STATUS='NEW')
     CLOSE(7,STATUS='KEEP')
     GOTO 5000
4050 OPEN (7,FILE="&PAT5.XXX",STATUS='NEW')
     CLOSE(7,STATUS='KEEP')
C
3002 FORMAT(11X,51(1H*),/
    1, 11X, '*          A-I-R-Q    POST-PROCESSOR              *',/
    2, 11X, '*   ESTIMATION OF TIME-SPENT PER DRIVING MODE      *',/
    3, 11X, '* FROM THE OUTPUT OF "FOUR-STEP" REGIONAL MODELS  *',/
    4, 11X,1H*,49(1H-),1H*)
3004 FORMAT(11X,1H*,49X,1H*)
3006 FORMAT(11X, '*    1. Run the Program                           *'
    1,/11X, '*    2. View Network Statistics                     *'
    2,/,11X, '*    3. View Link Summary Performance              *'
    3,/,11X, '*    4. View Link Specific Vehicle-Activity        *'
    4,/,11X, '*    5. Exit                                       *')
3008 FORMAT(11X,51(1H*))
3010 FORMAT(/,12X,'Enter Menu Choice  '\)
3012 FORMAT (/,12X,'Enter Input File Name:  '\)
3014 FORMAT (A15)
3016 FORMAT (/,12X,'File does not exist -- Re-enter (R) or Quit (Q) '\)
3018 FORMAT (A1)
3020 FORMAT (/,12X, 'Network Statistics'
    +/,15X,'Enter Output File  '\)
3022 FORMAT (/,12X,'File exists -- Re-enter (R) or Overwite (O) '\)
3026 FORMAT (/,12X,'Do you want Link Specific Veh-Activity Output',1X,
    +'(y/n) '\)
3028 FORMAT (/15X,' Enter Output File  '\)
3030 FORMAT ('LIST ',A15)
3032 FORMAT (/,12X,'Do you want Link Performance Summary Output',1X,
    +'(y/n) '\)
3040 FORMAT (15X, 'Program Running--Please wait..')
5000 END
C*****************************************************
     SUBROUTINE CLRSCR
C*****************************************************
     CHARACTER*1 CH(4)
     CH(1)=CHAR (27)
     CH(2)='['
     CH(3)='2'
     CH(4)='J'
     WRITE (*,*) ' ',CH
     RETURN
     END
```

```
C
C*******************************************************************
      SUBROUTINE AIRQM
C     MAIN DATA PROCESSING/CALCULATIONS ROUTINE
C     ROUTINE COMMON TO OFFLINE AND INTERACTIVE PROGRAM VERSION
C*******************************************************************
      COMMON/BLK1/SP(6,8,4)
      COMMON/BLK2/SF(14,15,8),SPDN(14,8),ACCN(15,8),SUMN(8)
      COMMON/BLK3/LT(14,15,15)
      COMMON/BLK4/IFLAG
      COMMON/BLK5/TNW(3)
      INTEGER*4 ANODE,BNODE,CPT,FSPD,VOL
      REAL VA(14,15),ACC(15),SPD(14),TLINK(4)
C
C Initialize variables, get tables with relationships
      CALL INITBL
      ICOUNT=0
C
      IF (IFLAG.GE.1) THEN
      WRITE(3,101)
      WRITE (3,102)
      ENDIF
C Read and process link input/output from the MINUTP planning model
 1000 READ(2,201,END=100) ANODE,BNODE,DIST,FSPD,CPT,JF,NA,VOL,CSPD,IC,ID
     +,VMT,VHT
C
      TNW(1)=TNW(1)+VMT
      TNW(2)=TNW(2)+VHT
      DIST=DIST/100.
      VMT=VMT/100.
      CSPD=AMIN0(FSPD,CSPD/10.)
      VHT=VHT/6000.
      DELAY=VHT-(VMT/FSPD)
      IF (DELAY.LE.0.00001) DELAY=0.00
      TNW(3)=TNW(3)+DELAY
C
C Estimate the time-spent on each link based on link type (ID)
C ACCUMULATE STATISTICS FOR THE NETWORK (FAC TYPE)
C
      IF(IFLAG.EQ.2) WRITE (4,203) ANODE,BNODE,JF,NA,VHT
      DO 10 L=1,4
 10   TLINK(L)=0.0
      DO 12 J=1,15
 12   ACC(J)=0
      DO 14 K=0,13
 14   SPD(K)=0
      SUM=0.0
C
      IF(IC.GT.100) THEN
       IF(ID.LE.2) ID1=13
       IF(ID.GE.3) ID1=14
       IF(ID.EQ.7 .OR. ID.EQ.8) ID1=15
       GOTO 555
      ENDIF
      ID1=ID
C
```

```
  555 DO 16 K=0,13
      DO 16 J=1,15
      ITEMP=LT(K,J,ID1)
      IF (K.EQ.0 .AND. DELAY.LE.0.0) ITEMP=0
      IF (K.EQ.1 .AND. DELAY.LE.0.0) ITEMP=LT(0,J,ID)+LT(1,J,ID)
      VA(K,J)=(60*VHT)*ITEMP/10000.
      SPD(K)=SPD(K)+VA(K,J)
      ACC(J)=ACC(J)+VA(K,J)
      SF(K,J,JF)=SF(K,J,JF)+VA(K,J)/60.
      SUM=SUM+VA(K,J)
   16 CONTINUE
C
      DO 333 K=0,13
  333 SPDN(K,JF)=SPDN(K,JF)+SPD(K)/60.
      DO 444 J=1,15
  444 ACCN(J,JF)=ACCN(J,JF)+ACC(J)/60.
      SUMN(JF)=SUMN(JF)+SUM/60.
C
      IF(IFLAG.EQ.2) THEN
       WRITE (4,470)
       WRITE (4,480) (K*5,(VA(K,L),L=1,15),SPD(K),K=0,13)
       WRITE (4,485) (ACC(J),J=1,15),SUM
       WRITE (4,490)
      ENDIF
C
C Calculate link performance and veh-activity summary statistics
      TLINK(1)=(ACC(8)-VA(0,8))/60.
      DO 50 I=9,15
   50 TLINK(2)=TLINK(2)+(ACC(I)-VA(0,I))
      TLINK(2)=TLINK(2)/60.
      DO 60 I=1,7
   60 TLINK(3)=TLINK(3)+(ACC(I)-VA(0,I))
      TLINK(3)=TLINK(3)/60.
      TLINK(4)=(SPD(0))/60.
      DO 70 L=1,4
      SP(NA,JF,L)=SP(NA,JF,L)+TLINK(L)
   70 CONTINUE
      IF (IFLAG.GE.1) THEN
      WRITE(3,202) ANODE,BNODE,DIST,FSPD,CPT,JF,NA,VOL,CSPD,IC,VMT,VHT,
     +DELAY,(TLINK(J),J=1,4)
      ENDIF
C
C********************************
      ICOUNT=ICOUNT+1
      I1=MOD(ICOUNT,100)
      IF (I1.LE.0)  WRITE (*,600) ICOUNT
      GOTO 1000
C Print out Network Statistics
      WRITE (3,490)
  100 CLOSE(2, STATUS='KEEP')
      CALL RESULT1
      CALL RESULT2
      STOP
  470 FORMAT (5X,'TIME-SPENT(Veh-min) BY SPEED(mph) and ACCELERATION(mph
     +/sec)'/,
     +'"MPH"  -7  -6    -5    -4    -3    -2    -1    0
```

```
  +   +1    +2    +3    +4    +5  +6  +7',  '    TOTAL'
  +/,124('='))
 480 FORMAT (14(I3,2X,2F5.1,11F8.1,2F5.1,F10.1/))
 485 FORMAT ('TOTAL',2F5.1,11F8.1,2F5.1,F10.1)
 101 FORMAT (/, 105('='),/, 4X,'LINK CHARACTERISTICS',
  +22X, 'LINK PERFORMANCE',22X, 'VEHICLE ACTIVITY',/,105('='))
 102  FORMAT (4X, 'LINK',3X,'DIST',2X,'SP  CAPA',2X,'F A',
  +5X,'VOL',3X,'CSP',2X,'VC',7X,'VMT',5X,'VHT',5X,'VHD',5X,'CRUI',
  +4X,'ACC',4X,'DEC',3X,'IDLE')
 201  FORMAT(2I5,F5.0,2I5,2I1,I5,F5.0,I5,I2,5X,2F9.0)
 202  FORMAT(2I5,F5.2,I4,I6,1X,2I2,3X,I5,F6.1,I4,1X,F9.2,F8.2,1X,F7.2,
  +2X,4F7.2)
 203  FORMAT (/,124('=')/,1X,'LINK#:',1X,2I5,3X,'FACILITY TYPE:',
  +I2,2X,'AREA TYPE:',I2,4X,'VHT(Veh-hr):',1X,F10.2)
 490  FORMAT (124('='))
 600  FORMAT (1X,'LINKS PROCESSED:',1X,I6)
     END
C****************************************************************
     SUBROUTINE RESULT2
C OUTPUT LINK SUMMARIES PER FACILITY TYPE AND AREA TYPE
C OUTPUT FILE:TABLE1.OUT
C*****************************************************************
     COMMON/BLK1/SP(6,8,4)
     CHARACTER*12 AREA(0:5),MODE(4)
     REAL SUMA(0:5),SUMF(8)
     DATA AREA /'CORE', 'CBD', 'UBD', 'URBAN', 'SUBURBAN', 'RURAL'/
     DATA MODE /'CRUISE','ACCELERATION','DECELERATION','IDLE'/
C    **********************
     WRITE (5,500)
     DO 100 L=1,4
     WRITE (5,700) MODE(L)
     DO 12 J=1,8
  12 SUMF(J)=0.0
     DO 10 K=0,5
  10 SUMA(K)=0.0
     SUM=0.0
     DO 200 K=0,5
     DO 200 J=1,8
     SUM=SUM+SP(K,J,L)
     SUMA(K)=SUMA(K)+SP(K,J,L)
     SUMF(J)=SUMF(J)+SP(K,J,L)
 200 CONTINUE
 101 FORMAT(1X,6F10.0)
     WRITE (5,1200)
     WRITE (5,1000)
     WRITE (5,1100) (AREA(K),(SP(K,J,L),J=1,8),SUMA(K),K=0,5)
     WRITE (5,1250) (SUMF(J),J=1,8),SUM
     WRITE (5,1260)
 100 CONTINUE
C    **********************
     RETURN
 500  FORMAT(1H1,'      SUMMARY STATISTICS FOR THE NETWORK')
 700  FORMAT (1X,'TOTAL TIME-SPENT IN',1X,A12,1X,'MODE (Veh-h)')
1000  FORMAT (' AREA',20X,'                   FACILITY TYPE',/,
  +' TYPE            1         2         3          4',11X,
  +'5          6          7          8        TOTAL'/,130('='))
```

```
1100  FORMAT (6(1X,A8,1X,8F12.2,F14.2/))
1200  FORMAT (130('='))
1250  FORMAT (1X,'TOTAL',4X,8F12.2,F14.2)
1260  FORMAT(130('='),/,/)
      END
C****************************************************************
      SUBROUTINE RESULT1
C TIME-SPENT FOR THE NETWORK, AND PER FACILITY TYPE/AREA TYPE
C NETWORK SUMMARY STATISTICS
C OUTPUT FILE:TABLE1.OUT
C****************************************************************
      COMMON/BLK2/SF(14,15,8),SPDN(14,8),ACCN(15,8),SUMN(8)
      COMMON/BLK5/TNW(3)
      REAL SPD(14),ACC(15),SUM,VA(14,15)
C PRINT  TIME-SPENT PER FACILITY TYPE
      DO 10 M=1,8
      WRITE (5,300) M
      WRITE (5,470)
      WRITE (5,480) (K*5,(SF(K,L,M),L=1,15),SPDN(K,M),K=0,13)
      WRITE (5,485) (ACCN(J,M),J=1,15),SUMN(M)
      WRITE (5,490)
 10   CONTINUE
C
C Calculate time-spent for the total network
      DO 40 K=0,13
      DO 40 J=1,15
 40   VA(K,J)=0.0
      DO 70 K=0,13
      DO 80 J=1,15
      DO 75 M=1,8
 75   VA(K,J)=VA(K,J)+SF(K,J,M)
 80   CONTINUE
 70   CONTINUE
      SUM=0.0
      DO 212 J=1,15
212   ACC(J)=0.0
      DO 214 K=0,13
214   SPD(K)=0.0
      DO 400 K=0,13
      DO 400 J=1,15
      SPD(K)=SPD(K)+VA(K,J)
      ACC(J)=ACC(J)+VA(K,J)
      SUM=SUM+VA(K,J)
400   CONTINUE
      WRITE (5,800)
      WRITE (5,470)
      WRITE (5,480) (K*5,(VA(K,L),L=1,15),SPD(K),K=0,13)
      WRITE (5,485) (ACC(J),J=1,15), SUM
      WRITE (5,490)
C
      TNWS=60*TNW(1)/TNW(2)
      TNW(1)=TNW(1)/100.
      TNW(2)=TNW(2)/6000.
      WRITE (5,600) (TNW(I),I=1,3)
      WRITE (5,650) TNWS
      RETURN
```

```
C
 800 FORMAT (130('='),/10X, 'VEHICLE ACTIVITY FOR THE TOTAL NETWORK')
 300 FORMAT (1X,'VEHICLE ACTIVITY FOR FACILITY TYPE:',2X,I2)
 470 FORMAT (5X,'TIME-SPENT (Veh-hr) BY SPEED(mph) and ACCELERATION(mph
    +/sec)'/,
    +'"MPH"  -7   -6    -5    -4    -3    -2    -1
    + 0     +1    +2    +3    +4    +5   +6   +7',5X,
    +'TOTAL'/,130('='))
 480 FORMAT (14(I3,2X,F5.1,F6.1,3F8.1,5F9.1,3F8.1,F6.1,F5.1,F10.1/))
 485 FORMAT ('TOTAL',F5.1,F6.1,3F8.1,5F9.1,3F8.1,F6.1,F5.1,F10.1)
 490 FORMAT (130('='),/,/)
 600 FORMAT (//,130('='),/10X,'NETWORK SUMMARY STATISTICS'/,10X,
    +'TOTAL DISTANCE TRAVELED (VMT):',5X,F10.1/,10X,'TOTAL TRAVEL TIME
    +(VHT):',11X,F10.1,/10X,'TOTAL DELAY (VHD):',17X,F10.1)
 650 FORMAT (10X,'AVERAGE NETWORK SPEED (MPH):',7X,F10.1,/130('='))
    END
C*********************************************************************
    SUBROUTINE INITBL
C Initialization of Variables
C Read File with Look-Up Tables (% Time Spent per Link Type)
C*********************************************************************
    COMMON/BLK1/SP(6,8,4)
    COMMON/BLK2/SF(14,15,8),SPDN(14,8),ACCN(15,8),SUMN(8)
    COMMON/BLK3/LT(14,15,15)
    COMMON/BLK5/TNW(3)
    DO 40 I=0,13
    DO 40 J=1,15
    DO 1 L=1,8
  1 SF(I,J,L)=0.0
 40 CONTINUE
    DO 3 I=0,5
    DO 3 J=1,8
    DO 3 L=1,4
  3 SP(I,J,L)=0.0
    DO 60 J=1,15
    DO 60 I=1,8
 60 ACCN(J,I)=0.0
    DO 50 I=1,8
 50 SUMN(I)=0.0
    DO 70 I=1,14
    DO 70 J=1,8
 70 SPDN(I,J)=0.0
    DO 5 I=1,3
  5 TNW(I)=0.0
C
C-Open the tables file (AIRQTBL.TBL)
C
    OPEN (1,FILE='AIRQTBL.TBL', ACCESS='SEQUENTIAL')
    DO 10 N=1,15
    DO 20 K=0,13
 20 READ(1,*)(LT(K,J,N),J=1,15)
 10 CONTINUE
    RETURN
    END
```

APPENDIX F. MINUTP QUEUEING POST-PROCESSOR

```
$------------------
$ POSTMTC.SET          QUEUING POST-PROCESSOR FOR MINUTP
$                      1120 ZONE 1990 AM PEAK MTC BASE NETWORK
$                      ORIGINAL R G DOWLING 1991/93
$                      MODIFIED FOR ARB STUDY A. SKABARDONIS, 1994
$------------------
*PGM NETMRG LOADPS.NET LOAD27.NET
NET 0=LOADPS.NET,1=LOAD27.NET
$
$ SELECT NETWORK LINKS TO BE PROCESSED
$ EXCLUDE DUMMY NODES AND PROCESS ONLY LINKS WITH VOLUMES
 SKIP FT=6
IF VOL=1-999999
$
$ SET PARAMETERS FOR BPR CURVE (DEFAULT: 1990 MTC)
COMP CFA=20
COMP BETA=10
COMP KAP=100
$
$ BASIC CALCULATIONS
COMP CAPA=CAP*LANE
$
$ DETERMINE THE FREE-FLOW SPEED FROM SPDC/CAPC (1990 MTC NETWORK)
  @ FT=1,AT=0-1 FFS=40
  @ FT=1,AT=2-3 FFS=45
  @ FT=1,AT=4-5 FFS=50
  @ FT=2,AT=0-1 FFS=55
  @ FT=2,AT=2-3 FFS=60
  @ FT=2,AT=4-5 FFS=65
  @ FT=3,AT=0-1 FFS=40
  @ FT=3,AT=2-3 FFS=45
  @ FT=3,AT=4   FFS=50
  @ FT=3,AT=5   FFS=55
  @ FT=4,AT=0   FFS=20
  @ FT=4,AT=1   FFS=25
  @ FT=4,AT=2-3 FFS=30
  @ FT=4,AT=4   FFS=35
  @ FT=4,AT=5   FFS=40
  @ FT=5,AT=0-1 FFS=30
  @ FT=5,AT=2-3 FFS=35
  @ FT=5,AT=4-5 FFS=40
  @ FT=7,AT=0   FFS=25
  @ FT=7,AT=1   FFS=30
  @ FT=7,AT=2-3 FFS=35
  @ FT=7,AT=4   FFS=40
  @ FT=7,AT=5   FFS=45
  @ FT=8,AT=0-1 FFS=25
  @ FT=8,AT=2-3 FFS=30
  @ FT=8,AT=4-5 FFS=35
$
 COMP QUEUE1=0.0                         INITIAL QUEUE AT START OF PERIOD 1.
$
$ EACH TIME SLICE = 1.0 HOURS
$ DISTANCES ARE MILES*100
$ SPEEDS ARE IN MPH*10
$ VHT IS (VEH-H)*10
$
$ ---------COMPUTE QUEUE AND SPEED FOR FIRST HOUR--5-6 AM-----------
$
$ COMPUTE HOURLY VOLUMES
$
 COMP HRVOL=VOL*0.142                            AM PK HR VOL 5-6 AM
 COMP VC=100.0*HRVOL/CAPA
 COMP QUEUE2=QUEUE1+HRVOL-CAPA
 IF QUEUE2=1-999999                              QUEUE CALCULATIONS
   IF FT=1-2                                     FWYS
     COMP FREESPD=KAP*FFS/10./(1.0+CFA/100)      SPEED AT V/C=1.0
   ELSE                                          OTHER FACILITIES
     COMP FREESPD=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/200.0)**BETA)      SPEED AT 0.5*V/C
   ENDIF
```

```
    COMP QUEUESPD=25.0/528.0*CAPA/LANE
    COMP QUELNGTH=(QUEUE1+QUEUE2)/2.0/LANE*25.0/52.8
    COMP DIFF=QUELNGTH-DIST
    IF DIFF=1-999999
       COMP LENGTH=QUELNGTH
    ELSE
       COMP LENGTH=DIST
    ENDIF
    COMP SPEED=LENGTH/(QUELNGTH/QUEUESPD+(LENGTH-QUELNGTH)/FREESPD))
  ELSE
    COMP QUEUE2=0.0                                   NO QUEUE CALC.
    COMP SPEED=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/100.0)**BETA)
    COMP LENGTH=DIST
  ENDIF
  COMP QUEUE1=QUEUE2
  COMP VHT=HRVOL*LENGTH/SPEED
  COMP PKVOL=HRVOL
$
$ ---------COMPUTE QUEUE AND SPEED FOR SECOND HOUR--6-7 AM------------
$
$ COMPUTE HOURLY VOLUMES
$
  COMP HRVOL=VOL*0.415                                AM PK HR VOL 6-7 AM
  COMP VC=100.0*HRVOL/CAPA
  COMP QUEUE2=QUEUE1+HRVOL-CAPA
  IF QUEUE2=1-999999                                  QUEUE CALCULATIONS
    IF FT=1-2                                         FWYS
      COMP FREESPD=KAP*FFS/10./(1.0+CFA/100)          SPEED AT V/C=1.0
    ELSE                                              OTHER FACILITIES
      COMP FREESPD=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/200.0)**BETA)   SPEED AT 0.5*V/C
    ENDIF
    COMP QUEUESPD=25.0/528.0*CAPA/LANE
    COMP QUELNGTH=(QUEUE1+QUEUE2)/2.0/LANE*25.0/52.8
    COMP DIFF=QUELNGTH-DIST
    IF DIFF=1-999999
       COMP LENGTH=QUELNGTH
    ELSE
       COMP LENGTH=DIST
    ENDIF
    COMP SPEED=LENGTH/(QUELNGTH/QUEUESPD+(LENGTH-QUELNGTH)/FREESPD))
  ELSE
    COMP QUEUE2=0.0                                   NO QUEUE CALC.
    COMP SPEED=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/100.0)**BETA)
    COMP LENGTH=DIST
  ENDIF
  COMP QUEUE1=QUEUE2
  COMP VHT=VHT+HRVOL*LENGTH/SPEED
  COMP PKVOL=PKVOL+HRVOL
$
$ ---------COMPUTE QUEUE AND SPEED FOR THIRD HOUR--7-8 AM------------
$
$ COMPUTE HOURLY VOLUMES
$
$ COMP HRVOL=VOL                                      AM PK HR VOL 7-8 AM
  COMP VC=100.0*HRVOL/CAPA
  COMP QUEUE2=QUEUE1+HRVOL-CAPA
  IF QUEUE2=1-999999                                  QUEUE CALCULATIONS
    IF FT=1-2                                         FWYS
      COMP FREESPD=KAP*FFS/10./(1.0+CFA/100)          SPEED AT V/C=1.0
    ELSE                                              OTHER FACILITIES
      COMP FREESPD=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/200.0)**BETA)        SPEED AT 0.5*V/C
    ENDIF
    COMP QUEUESPD=25.0/528.0*CAPA/LANE
    COMP QUELNGTH=(QUEUE1+QUEUE2)/2.0/LANE*25.0/52.8
    COMP DIFF=QUELNGTH-DIST
    IF DIFF=1-999999
       COMP LENGTH=QUELNGTH
    ELSE
       COMP LENGTH=DIST
    ENDIF
    COMP SPEED=LENGTH/(QUELNGTH/QUEUESPD+(LENGTH-QUELNGTH)/FREESPD))
  ELSE
    COMP QUEUE2=0.0                                   NO QUEUE CALC.
```

```
      COMP SPEED=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/100.0)**BETA)
      COMP LENGTH=DIST
    ENDIF
    COMP QUEUE1=QUEUE2
    COMP VHT=VHT+HRVOL*LENGTH/SPEED
    COMP PKVOL=PKVOL+HRVOL
$
$ ---------COMPUTE QUEUE AND SPEED FOR FOURTH HOUR--8-9 AM-----------
$
$ COMPUTE HOURLY VOLUMES
$
    COMP HRVOL=VOL*0.940                                AM PK HR VOL 8-9 AM
    COMP VC=100.0*HRVOL/CAPA
    COMP QUEUE2=QUEUE1+HRVOL-CAPA
    IF QUEUE2=1-999999                                  QUEUE CALCULATIONS
      IF FT=1-2                                         FWYS
        COMP FREESPD=KAP*FFS/10./(1.0+CFA/100)          SPEED AT V/C=1.0
      ELSE                                              OTHER FACILITIES
        COMP FREESPD=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/200.0)**BETA)        SPEED AT 0.5*V/C
      ENDIF
      COMP QUEUESPD=25.0/528.0*CAPA/LANE
      COMP QUELNGTH=(QUEUE1+QUEUE2)/2.0/LANE*25.0/52.8
      COMP DIFF=QUELNGTH-DIST
      IF DIFF=1-999999
         COMP LENGTH=QUELNGTH
      ELSE
         COMP LENGTH=DIST
      ENDIF
      COMP SPEED=LENGTH/(QUELNGTH/QUEUESPD+(LENGTH-QUELNGTH)/FREESPD))
    ELSE
      COMP QUEUE2=0.0                                   NO QUEUE CALC.
      COMP SPEED=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/100.0)**BETA)
      COMP LENGTH=DIST
    ENDIF
    COMP QUEUE1=QUEUE2
    COMP VHT=VHT+HRVOL*LENGTH/SPEED
    COMP PKVOL=PKVOL+HRVOL
$
$ ---------COMPUTE QUEUE AND SPEED FOR FIFTH HOUR--9-10 AM-----------
$
$ COMPUTE HOURLY VOLUMES
$
$ COMP HRVOL=VOL*0.708                                  AM PK HR VOL 9-10 AM
    COMP VC=100.0*HRVOL/CAPA
    COMP QUEUE2=QUEUE1+HRVOL-CAPA
    IF QUEUE2=1-999999                                  QUEUE CALCULATIONS
      IF FT=1-2                                         FWYS
        COMP FREESPD=KAP*FFS/10./(1.0+CFA/100)          SPEED AT V/C=1.0
      ELSE                                              OTHER FACILITIES
        COMP FREESPD=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/200.0)**BETA)        SPEED AT 0.5*V/C
      ENDIF
      COMP QUEUESPD=25.0/528.0*CAPA/LANE
      COMP QUELNGTH=(QUEUE1+QUEUE2)/2.0/LANE*25.0/52.8
      COMP DIFF=QUELNGTH-DIST
      IF DIFF=1-999999
         COMP LENGTH=QUELNGTH
      ELSE
         COMP LENGTH=DIST
      ENDIF
      COMP SPEED=LENGTH/(QUELNGTH/QUEUESPD+(LENGTH-QUELNGTH)/FREESPD))
    ELSE
      COMP QUEUE2=0.0                                   NO QUEUE CALC.
      COMP SPEED=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/100.0)**BETA)
      COMP LENGTH=DIST
    ENDIF
    COMP QUEUE1=QUEUE2
    COMP VHT=VHT+HRVOL*LENGTH/SPEED
    COMP PKVOL=PKVOL+HRVOL
$
$ ---------COMPUTE QUEUE AND SPEED FOR SIXTH HOUR--10-11 AM-----------
$
$ COMPUTE HOURLY VOLUMES
$
```

```
  COMP HRVOL=VOL*0.778                               AM PK HR VOL 10-11 AM
  COMP VC=100.0*HRVOL/CAPA
  COMP QUEUE2=QUEUE1+HRVOL-CAPA
  IF QUEUE2=1-999999                                 QUEUE CALCULATIONS
    IF FT=1-2                                        FWYS
      COMP FREESPD=KAP*FFS/10./(1.0+CFA/100)         SPEED AT V/C=1.0
    ELSE                                             OTHER FACILITIES
      COMP.FREESPD=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/200.0)**BETA)       SPEED AT 0.5*V/C
    ENDIF
    COMP QUEUESPD=25.0/528.0*CAPA/LANE
    COMP QUELNGTH=(QUEUE1+QUEUE2)/2.0/LANE*25.0/52.8
    COMP DIFF=QUELNGTH-DIST
    IF DIFF=1-999999
       COMP LENGTH=QUELNGTH
    ELSE
       COMP LENGTH=DIST
    ENDIF
    COMP SPEED=LENGTH/(QUELNGTH/QUEUESPD+(LENGTH-QUELNGTH)/FREESPD))
  ELSE
    COMP QUEUE2=0.0                                  NO QUEUE CALC.
    COMP SPEED=(KAP*FFS/10.0)/(1.0+(CFA/100.0)*(VC/100.0)**BETA)
    COMP LENGTH=DIST
  ENDIF
  COMP QUEUE1=QUEUE2
  COMP VHT=VHT+HRVOL*LENGTH/SPEED
  COMP PKVOL=PKVOL+HRVOL
$
$-------------------------Calculate Totals-----------------------------
$
  COMP VMT=DIST*PKVOL/100.0
  COMP SPEED=100.*VMT/VHT
  LIST A=1-4,B=6-9,FT=11-12,AT=13-15,VOL=18-23,PKVOL=24-30
  LIST VMT=32-37,VHT=39-42,SPEED=45-50
  SUM VMT,VHT,PKVOL,QUEUE2
  TAB VMT,FT=1-8,SPEED=0-70-5
  TAB VMT,SPEED=0-70-5
  TITLE 3
MTC 1120 ZONE NETWORK AM PEAK HOUR HIGHWAY SYSTEM YEAR 1990
AM PEAK PERIOD (5:00 AM TO 11:00 AM)
NODE NODE FT AT     VOL  PKVOL    VMT  VHT   SPEED
ENDIF        FOR  VOL=1-99999
$
$------------------------
*> COPY *.PRN MTC90.OUT
*> DEL *.PRN
*> LIST MTC90.OUT
$------------------------
```

APPENDIX G. PROGRAM FOR PROCESSING NETSIM TRAJECTORY FILES

```
PROGRAM TABLE4
C
C-----This Program Reads an LU32 file written by NETSIM 4.0
C-----The unpacked data by time period is written to table1.out
C-----The tabulated data by link is written to table2.out
C-----TABLE3.OUT HAS AGGREGATED SPEED/ACCEL DATA FOR ALL LINKS
C-----Written 12/11/93 R.Dowling, revised 12/16/93 RGD
C
C-----Variable Definitions
C
C    IL   = Link Number
C    DIST = Distance from upstream node (feet)
C    ITYP = Vehicle Type
C    IACC = Acceleration Category (-9 to +9 fpss)
C    ISPD = Speed Category (0 to 70 fps)
C    INW  = number of 4-byte variables to be read for each one second
C           time interval
C    IDE  = INW+1 because netsim writes one extra variable that appears
C           to be trash.
C    ILMAX= Highest Link Number
C    SUMTAB        = Total number of vehicle-seconds in link table
C    SUMSPD        = Sum of veh-secs times speed for link table
C                 Also used for Mean link speed. In feet per sec
C    TABLE(J,K,L)  = Table of vehicle-seconds stratified by link number (j)
C                 speed category (k), and accelration category (l).
C                 Also used to store the proportion of the total vehicle
C                 seconds in each category. Link 151 is for total.
C    MPHTAB(J,K) = Aggregated table by mph category, showing total veh-secs
C           for all links by 5 mph category and 1 mph/sec accel category.
C    TRASH1 = ONE BYTE OF TRASH AT BEGIN OF UNFORMATTED SEQUENTIAL FILE
C    LENGTH = NUMBER OF BYTES FOLLOWING IN LOGICAL RECORD,
C           THIS VARIABLE MAY BE ONE TO FOUR BYTES LONG IN LU32
C    LENGTH1, LENGTH2, LENGTH3, LENGTH4 = one byte portions of LENGTH RECORD
C    L2 = USED TO STORE NUMBER OF BYTES AND MAX DABUF WORD TO BE READ
C    LEFTOVER = NUMBER OF INT*4 VARIABLES REMAINING TO BE READ
C
C-----SPECIAL NOTE ON LU32 FILE FOR NETSIM 4
C
C    NETSIM is written in LAHEY FORTRAN F77L-EM/32
C    FORMAT OF LU 32 FILE =
C    [TRASH1][LENGTH][...RECORD...][LENGTH'][LENGTH"][..RECORD..][LENGTH'"]
C    [1 byte]  [*]   [Length*bytes][1 byte]  [*]   [Length"*bytes]  [*]
C    The lowest 2 bits of LENGTH give the number of bytes (0-3) that follow that
C    are part of the LENGTH record itself.
C    The next higher 6 bits plus the remaining bytes in LENGTH give the
C    number of bytes that follow in the logical record.
C    LENGTH' = LENGTH + Number of Bytes in LENGTH
C
C-----Variable Type Declarations
C
      IMPLICIT INTEGER*2 (A-Q, S-V, X), REAL (R,Z), LOGICAL (W, Y)
      INTEGER*4  DATBUF(502),LENGTH,L1,L2,L3,L4,LM
```

```
      INTEGER*2  TABLE(1:151,0:70,-9:9), MPHTAB(0:10,-7:7)
      INTEGER*4  MEANSPD,SUMTAB,SUMSPD
      INTEGER*1  TRASH1, LENGTH1, LENGTH2, LENGTH3, LENGTH4
C
C-----OPEN FILES
C
      OPEN ( 1, FILE = 'LU32', FORM = 'BINARY',
     +         ACCESS = 'DIRECT', STATUS = 'OLD', RECL=1)
C     OPEN (2,FILE='TABLE1.OUT', FORM = 'FORMATTED', STATUS ='UNKNOWN')
C     OPEN (3,FILE='TABLE2.OUT', FORM = 'FORMATTED', STATUS ='UNKNOWN')
      OPEN (4,FILE='T3-SLO.OUT', FORM = 'FORMATTED',STATUS ='UNKNOWN')
      OPEN (5,FILE='T4-SLO.OUT', FORM = 'FORMATTED',STATUS ='UNKNOWN')
C
C-----INITIALIZE
C
      ILMAX = 0
      EATBL = 19
      EVTBL = 71
      DO 5 J=1,151
      DO 5 K=0,70
      DO 5 L=-9,9
        TABLE (J,K,L)=0
    5 CONTINUE
      DO 6 K= 0,10
      DO 6 L=-7, 7
        MPHTAB(K,L)=0
    6 CONTINUE
C
C-----WRITE HEADER ON FILES
C
C     WRITE (2,100)
C 100 FORMAT ('NETSIM 3.0 LU 32 FILE CONTENTS',/,
C    +'  Entries Time-secs      Link   Dist-ft  Veh.Type Speed-fps Acc
C    +el-fpss')
C
C-----READ TRAJECTORY DATA FROM UNIT 32 (READ FIRST 3 WORDS IN ARRAY)
C
       READ (1,END=1000) TRASH1
   10 CONTINUE
       READ (1,END=1000) LENGTH1
C-------I AM ASSUMING HERE THAT THIS INSTANCE OF LENGTH1 ALWAYS EQUALS 32
       READ (1,END=1000) DATBUF(1), DATBUF(2), LENGTH1
       IF (DATBUF(1) .LT. 0)  GO TO 1000
       INW = DATBUF(1)
C
C-------COMPUTE NUMBER OF ENTRIES AND TIME
C
       ITIME = DATBUF(2)
       WRITE (*,120) INW
  120  FORMAT(' Datbuf Size=',I10)
       WRITE (*,130) ITIME
  130  FORMAT (' Time =       ',I10)
       IF (INW .GT. 502) WRITE (2,135)
  135  FORMAT ('  NUMBER OF ENTRIES EXCEEDED 502, RESET TO 502')
```

```
      IDE = MIN0(502,INW)
      LEFTOVER = IDE - 2
      I=3
C
C----READ NUMBER OF BYTES IN LOGICAL RECORD
C
 20   READ (1,END=1000) LENGTH1
C
C----COMPUTE LENGTH RECORD
C     READ EACH BYTE (1-4), CONVERT NEGATIVE NUMBERS TO POSITIVE,
C     COMBINE INTO SINGLE LENGTH VARIABLE
C
      L1 = LENGTH1
      L2 = 0
      L3 = 0
      L4 = 0
      IF (LENGTH1.LT.0) L1 = LENGTH1+256
      LM = MOD(L1,2**2)
      IF (LM.EQ.0) THEN
        LENGTH = L1 / 2**2
      ENDIF
      IF (LM.EQ.1) THEN
        READ (1,END=1000) LENGTH2
        L2 = LENGTH2
        IF (LENGTH2.LT.0) L2 = LENGTH2+256
        LENGTH = L2 * 2**6 + L1 / 2**2
      ENDIF
      IF (LM.EQ.2) THEN
        READ (1,END=1000) LENGTH2, LENGTH3
        L2 = LENGTH2
        IF (LENGTH2.LT.0) L2 = LENGTH2+256
        L3 = LENGTH3
        IF (LENGTH3.LT.0) L3 = LENGTH3+256
        LENGTH = L3 * 2**14 + L2 * 2**6 + L1 / 2**2
      ENDIF
      IF (LM.EQ.3) THEN
        READ (1,END=1000) LENGTH2, LENGTH3, LENGTH4
        L2 = LENGTH2
        IF (LENGTH2.LT.0) L2 = LENGTH2+256
        L3 = LENGTH3
        IF (LENGTH3.LT.0) L3 = LENGTH3+256
        L4 = LENGTH4
        IF (LENGTH4.LT.0) L4 = LENGTH4+256
        LENGTH = L4 * 2**22 + L3 * 2**14 + L2 * 2**6 + L1 / 2**2
      ENDIF
      IF (LM.GT.3) WRITE (2,999)
C-----HERE WE START TO USE "LM" FOR THE NUMBER OF VARIABLES TO BE READ
      LM = LENGTH
      LEFTOVER = MAX((LEFTOVER - (LM/4)),0)
C     WRITE (*,22) IDE,LENGTH,LM,LEFTOVER,I
C     WRITE (2,22) IDE,LENGTH,LM,LEFTOVER,I
C 22  FORMAT ('IDE,LENGTH,LM,LEFTOVER,I=',110(5I5,/))
C
C----READ VEHICLE TRAJECTORIES
```

```
C   convert length in bytes into length in int*4, add 2 for Datbuf(1) and (2)
C   read "length" variables as long as leftover greater than zero
C
       LM = MAX0(MIN0(502,LM/4+I-1),0)
       II = MIN0(502,II)
       IF (LENGTH.EQ.0) GO TO 25
       READ (1,END=1000) (DATBUF(II),II=I,LM)
C       WRITE (2,23) I, LM, (DATBUF(II),II=I,LM)
C 23    FORMAT(' I, LM, DATBUF-I TO LM=',110(5I10,/))
       I = LM+1
C
C-----READ END LENGTH RECORD
C   NOTE END LENGTH EQUALS NUMBER OF BYTES BEFORE IT PLUS BYTES IN
C   LENGTH RECORD ITSELF (MOD(L1,2**2)+1
C
  25   READ (1,END=1000) LENGTH1
       LM = LENGTH + MOD(L1,2**2) + 1
       IF ((LM/2**22).GT.0) THEN
         READ (1,END=1000) LENGTH2, LENGTH3, LENGTH4
         GO TO 30
       ENDIF
       IF ((LM/2**14).GT.0) THEN
         READ (1,END=1000) LENGTH2, LENGTH3
         GO TO 30
       ENDIF
       IF ((LM/2**6).GT.0) THEN
         READ (1,END=1000) LENGTH2
         GO TO 30
       ENDIF
C
C-----GO BACK TO READ MORE IF STILL MORE TO GO
C
  30   IF (LEFTOVER .GT. 0) GO TO 20
C
C----UNPACK DATBUF ARRAY (FROM SUBROUTINE ENVTBL)
C
      DO 50 II=3,IDE,2
         IL = MOD(DATBUF(II),2**9)
         DIST = 32 * MOD(DATBUF(II)/2**9,2**6)
         ITYP= MOD (DATBUF(II+1)/2**7,2**3)
         IACC = MOD (DATBUF(II+1)/2**10,2**4)
         IF (DATBUF(II+1) .GE. 2**14) IACC = -IACC
         IACC = MIN0 (MAX0 (IACC, -EATBL/2), EATBL/2)
         ISPD = MIN0( MAX0(
    +     MOD(DATBUF(II+1),2**7) - IACC/2,0),EVTBL-1)
C
C-----ACCUMULATE TOTAL VEHICLE SECONDS BY SPEED AND ACCELERATION
CATEGORY
C   FOR EACH LINK. EACH OBSERVATION EQUALS ONE VEHICLE-SECOND.
C
      ILMAX= MIN0(MAX0(IL,ILMAX),150)
C      WRITE (*,150) INW,ITIME,IL,DIST,ITYP,ISPD,IACC
C      WRITE (2,150) INW,ITIME,IL,DIST,ITYP,ISPD,IACC
 150   FORMAT (7I10)
```

```
      IF ((IL.GT.150).OR.(IL.LE.0)) GO TO 10
      TABLE(IL,ISPD,IACC)=TABLE(IL,ISPD,IACC)+1
   50 CONTINUE
     GO TO 10
C
C-----COMPUTE VEHICLE-SECONDS AND MEAN SPEED BY LINK
C
 1000 CONTINUE
     DO 1300 J=1,ILMAX
      SUMTAB=0
      SUMSPD=0
      DO 1100 K=0,70
      DO 1100 L=-9,9
       SUMTAB= SUMTAB + TABLE(J,K,L)
       SUMSPD= SUMSPD + (K * TABLE(J,K,L))
 1100  CONTINUE
      IF(SUMTAB.EQ.0) GO TO 1300
.     MEANSPD= 100*SUMSPD/SUMTAB
C      WRITE (3,1210) J,SUMTAB,MEANSPD
 1210  FORMAT (' LINK # ',I3,' Total Veh-Secs= ',I8,
   +  '   Mean Speed 100ths of FPS =',I6)
C      WRITE (3,1220)
 1220 FORMAT ('Number of Vehicle-Seconds by speed(row) and acceleration
   +(col)',/,
   +'fps-9fpss -8 -7 -6 -5 -4 -3 -2 -1  0  1  2  3  4  5
   +  6  7  8  9',/, 80('='))
C      WRITE (3,1230) (K,(TABLE(J,K,L),L=-9,9),K=0,70)
 1230  FORMAT (71(I3,9I4,I5,9I4,/))
 1300 CONTINUE
C
C-----COMPUTE TOTAL VEHICLE-SECONDS AND MEAN SPEED ALL LINKS
C
    SUMTAB=0
    SUMSPD=0
    DO 1400 J=1,ILMAX
    DO 1400 K=0,70
    DO 1400 L=-9,9
      TABLE(151,K,L) = TABLE(151,K,L) + TABLE(J,K,L)
      KK = 1+K*3600.0/5280.0/5
      IF (K.EQ.0) KK=0
      LL = L * 3600.0/5280.0 + 0.5
      MPHTAB(KK,LL) = MPHTAB(KK,LL) + TABLE(J,K,L)
      SUMTAB= SUMTAB + TABLE(J,K,L)
      SUMSPD= SUMSPD + (K * TABLE(J,K,L))
1400 CONTINUE
   IF(SUMTAB.EQ.0)  GO TO 1450
     SUMSPD= 100*SUMSPD/SUMTAB
1450 WRITE (4,1460) ILMAX,SUMTAB,SUMSPD
   WRITE (5,1460) ILMAX,SUMTAB,SUMSPD
1460 FORMAT ('"TOTAL LINKS="',I3,'"Total Veh-Secs="',I8,
  +  '"Mean Speed 100ths of FPS="',I6)
   WRITE (4,1220)
   WRITE (4,1230) (K,(TABLE(151,K,L),L=-9,9),K=0,70)
   WRITE (4,1470)
```

```
      WRITE (5,1470)
 1470 FORMAT ('"Vehicle-Seconds by speed (MPH) (row) and acceleration (M
     +PH/SEC) (col)"',/,
     +'"mph" -7  -6  -5  -4  -3  -2  -1   0  +1  +2  +3  +4
     + +5  +6  +7', /, 80('='))
      WRITE (4,1480) (K*5,(MPHTAB(K,L),L=-7,7),K=0,10)
      WRITE (5,1480) (K*5,(MPHTAB(K,L),L=-7,7),K=0,10)
 1480 FORMAT (11(I3,15I5,/))
C
C-----COMPUTE PROPORTIONS BY CATEGORY, TOTAL FOR ALL LINKS
C
      IF(SUMTAB.EQ.0) GO TO 1865
      DO 1860 K=0,70
      DO 1860 L=-9,9
         TABLE(151,K,L) = 1000 * TABLE(151,K,L)/SUMTAB
 1860 CONTINUE
      DO 1863 K=0,10
      DO 1863 L=-7,7
         MPHTAB(K,L) = 1000 * MPHTAB(K,L)/SUMTAB
 1863 CONTINUE
 1865 WRITE (4,1870) ILMAX
 1870 FORMAT (' TOTAL LINKS=',I3)
      WRITE (4,1880)
 1880 FORMAT ('Proportion *1000 of Vehicle-Seconds by speed(row) and ac
     +celeration(col)',/,
     +'fps-9fpss -8 -7  -6  -5  -4  -3  -2  -1   0   1   2   3   4   5
     +  6   7   8   9',/, 80('='))
      WRITE (4,1230) (K,(TABLE(151,K,L),L=-9,9),K=0,70)
      WRITE (4,1890)
 1890 FORMAT ('PROPORTION of Vehicle-Seconds *1000 by MPH (row)        and acce
     +leration (MPH/SEC) (col)',/,
     +'mph -7mph/s-6  -5  -4  -3  -2  -1   0  +1  +2  +3  +4
     + +5  +6  +7',/, 80('='))
      WRITE (4,1480) (K*5,(MPHTAB(K,L),L=-7,7),K=0,10)
C
C----END
C
  999 FORMAT (' Length Record in LU 32 file exceeds 4 bytes./
     +Read problem. see statement 20')
 9999 STOP
      END
) and (2)
C     read "length" variables as long as leftover greater than zero
C
         LM =
```